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TRANSPORTATION CONTROL STRATEGY DEVELOPMENT FOR THE METROPOLITAN LOS ANGELES REGION

TRW TRANSPORTATION AND ENVIRONMENTAL OPERATIONS

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

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National Ambient Air Quality Standards - Air Quality Standards promulgated by the Environmental Protection Agency and published as a Federal Regulation in the Federal Register.

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VMT - Vehicle Miles Traveled
Vehicle Mix - distribution of motor vehicle population by age group.

LDV - light duty vehicle - less than 6500 lbs.
HDV - heavy duty vehicle - greater than 6500 lbs.

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Prepared by

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1.0 SUMMARY

This report presents the results of an analysis of a wide range of transportation control strategies aimed at reducing the air pollution in the California South Coast Air Basin (Metropolitan Los Angeles Region). The study was directed at identifying measures which would allow attainment of the national ambient air quality standards promulgated pursuant to the Clean Air Act of 1970. Target date for attainment of the standards is no later than 1977.

The pollutants of most concern in the Los Angeles area are carbon monoxide, nitrogen dioxide, and photochemical oxidants. Of these, the most severe problems have come from photochemical oxidants, primarily ozone. Since ozone is a secondary pollutant (i.e., it is not emitted directly as a pollutant), its control is dependent on eliminating the reactive hydrocarbons and nitrogen oxides which lead to its formation.

Stationary Sources — Presently, stationary source contributions to the overall problem are much less than mobile sources. However, they do comprise a very significant problem. Unless further controls of these sources are implemented, it is very likely the air quality standards will be exceeded from their emissions alone. No analysis was carried out on reductions possible from additional controls of these sources. The reductions stated in Chapter 10 have been assumed possible by EPA and have been accepted.

Mobile Sources -- There are many categories of mobile source emissions; this report has examined only the most significant categories -- in-use heavy and light duty motor vehicles. The evaluation of sources such as motorcycles, aircraft, tractors, etc. has been made by others. As motor vehicle controls become increasingly stringent, it will be important to investigate measures to control these sources. Left uncontrolled, they will contribute significant amounts of pollution by 1977.

1.1 Limitations of the Transportation Control Strategy Analysis

To be acceptable, an air pollution control strategy must reduce emission levels sufficiently to allow for the attainment and maintenance of national ambient air quality standards. In addition, an implementable transportation control strategy must consider the economic factors associated with its adoption as well as the social and political changes necessary to accommodate each specific control measure. The air quality benefits must be balanced against the social and economic costs of implementation. Limitations in the data and analytical methods became obvious during the course of the study, and care must be taken in the interpretation and evaluation of the control strategy recommendations. The proposed control strategy must be considered as an initial attempt to quantify the relationship between transportation processes and the regional air pollution problem. Further study is needed and warranted before embarking on controls that are likely to significantly disrupt the life styles of the Basin's residents. Several specific areas which need to be confirmed and validated by future study are listed below.

Emission Factors — The mobile source emission estimates in this study are based upon the best available emission factors. These emission factors are being revised in light of in-use and new vehicle testing programs being considered by the Environmental Protection Agency. It is highly recommended that new emission factors be utilized as they become available to recompute the severity of the mobile source generated emissions in the region.

Preliminary data indicates that emissions generated during the first few minutes of vehicle operation represent a large portion of the total emissions during any individual vehicle trip. This implies the reduction in the total vehicle trips may be more important than reducing the vehicle miles traveled. Unfortunately, the data relating to this phenomenon were not sufficiently developed to be used in this study.

It should be noted that stationary source estimates also suffer from inaccuracies in the projection of industrial growth. The change in emission factors for these sources, including the results from the application of as yet untested control technologies, is yet another source of error.

Traffic Data Projects — Historically, traffic data projections have not been collected with the intent of using them for estimating motor vehicle emissions. The data, including vehicle flow speeds and modal mixes, were reworked into the format necessary for emission calculations. Potential inaccuracies were introduced by this process. Projections of motor vehicle growth and VMT have been prepared by various agencies and little unanimity has been found concerning appropriate growth rates. Changes in traffic as well as ambient air quality should be closely monitored between now and 1977 so that deviations can be determined and appropriate adjustments made in the control strategy.

Analytical Technique — The key calculation in control measure assessment is relating emission levels to expected ambient air quality. Due to time and contractual constraints, it was not possible to utilize sophisticated modeling techniques to develop this relationship. Therefore, control strategy reductions were based on a rollback technique that relates existing emissions and air quality on a proportional basis. The use of modeling is highly recommended since it can consider the effects of local meteorological and topographical features and describes the geographical extent of the regional air pollution problem. Such procedures, using models now under development, should be utilized between now and 1977, and the results used to modify (if required) the control strategy recommended in this document.

1.2 Findings, Conclusions, and Recommendations

The following summarize the major findings, conclusions, and recommendations that have emerged as a result of this study.

Findings:

- Photochemical oxidants are substantially above the national ambient air quality standards a significant portion of the time.
- The geography and meteorology of the Basin contribute to the severity of the air pollution and the difficulties of its elimination.
- Presently, stationary source contributions to the air pollution problem are much less than those from mobile sources.

- A number of interrelated contributing factors have given rise to the present air pollution situation, including, physical growth, affluence, transportation and land use patterns, and governmental organization.

- The existing and projected alternative modes of transportation are inadequate to handle large increases in ridership.

- The present life styles of the Basin's residents are incompatible with the established air quality goals; no existing or foreseeable technological solutions would be able to solve the problem by 1977.

- Numerous studies of the problem have been conducted with agreement on one issue -- it will be extremely difficult to reach the air quality standards by 1977 without a massive change in the life styles of the Basin's residents. Such a change would be so disruptive, the "cure might be worse than the disease."

Conclusions:

- Additional stationary source controls will be necessary to achieve the air quality standards.

- Presently planned transportation improvement programs will result in very minor improvements of the air quality.

- All of the incentive type measures evaluated were relatively ineffective for significantly reducing the VMT.

- As a control measure, gasoline rationing appears to be the most effective means of significantly reducing VMT to the levels required to reach the air quality standards.

- The use of vehicles cannot be significantly restrained without providing some alternative means of transportation.

- Annual inspection/maintenance is necessary to obtain the full benefit of Federal and State vehicle emission control programs.

- The conversion of fleet vehicles to burn a gaseous fuel by 1975 would result in a significant reduction in emissions from vehicles which account for a disproportionate share of the VMT.

- No additional retrofit programs beyond the currently scheduled ones are warranted until completion of the State's evaluation programs.
- The implementation of evaporative loss controls from fueling operations should be instituted as soon as the appropriate devices become available.

Recommendations: (see Chapter 10.0)

It is recommended that the Phase I control measures be implemented as quickly as possible. The continuation of the State's ongoing motor vehicle control program plus these measures should result in a significant improvement of the air quality by 1977. The final decision regarding the implementation of the Phase II measure should be deferred until a careful analysis is made of the impact of such a program on the occupants of the region. At present, a large discrepancy exists between the VMT reduction necessary to attain the air quality standards, and the supply of alternative modes of transportation.

It is further recommended that a detailed evaluation be made of both the short and long range transportation needs of the region. As much as possible, these needs should be reflected in consistent short and long term planning goals.

2.0 INTRODUCTION

This report presents the results of a study to evaluate potential transportation control measures which will allow attainment of the national ambient air quality standards by 1977 in California's South Coast Air Basin (Los Angeles region). The control measures evaluated include an assessment of their technical effectiveness and institutional, political, and social feasibility. The study was conducted by the Transportation and Environmental Operations of TRW, Inc., in conjunction with the DeLeuw, Cather and Company organization, a fully owned subsidiary.

Chapters 2 and 3 present a brief description of the Los Angeles air pollution problem and review some of the work done to date on it. The following five chapters delve into various specific control strategies (Chapters 4 through 8). Many of these programs have been discussed for years in the South Coast Basin and for various reasons have not been widely implemented. The traffic (or VMT) oriented strategies are quantified for the first time to our knowledge (Chapters 6 and 7).

Chapter 9 discusses the supply of alternative modes of transportation and shows the lack of any foreseeable short range transportation system(s) which would be able to accomodate a large reduction in private automobile travel. Finally, Chapter 10 proposes a control strategy which would if implemented, in all probability, allow for attainment of the air quality standards. Unanswered is the question of how the residents of the Basin will be able to retain any significant degree of mobility if attempts are made to enforce such a control strategy.

Following the main body of the report are a series of appendices, each of which is self-contained, and designed to provide additional support material. Time was too limited to allow for a detailed analysis of all the reports which have been written on the subject in the Los Angeles area; the principal information sources which were used in preparing this document have been included in the bibliography.

2.1 Regional Description

The South Coast Air Basin as defined by the State of California, "consists of all of Orange and Ventura Counties and portions of Los Angeles, Riverside, San Bernardino and Santa Barbara Counties."(79) Geographically, the Basin is bounded on the west by the Pacific Ocean, on the south by San Diego County and by a series of mountain ranges on the north and west, namely, the San Gabriel, San Bernardino, San Gorgonio, San Jacinto, and Santa Ynez Mountains. A map of the Basin is shown in Figure 2.1.

Due to problems of data availability for information disaggregated beyond the county levels, some of the technical analysis performed in this report has considered the Basin to include all of Los Angeles, Ventura, Riverside, Orange and San Bernardino Counties. The difference between either definition, as far as the air pollution analyses is insignificant. The minor difference which does exist can be seen by comparing Tables 2.1 and 2.2. Part of the discrepancy in population estimates for 1970 can be accounted for by subtracting the military population estimates assumed in Table 2.2. As readily seen from the above tables, roughly one half of the State's population resides in the South Coast Air Basin, in a land area which comprises approximately six per cent of the State's total land area.

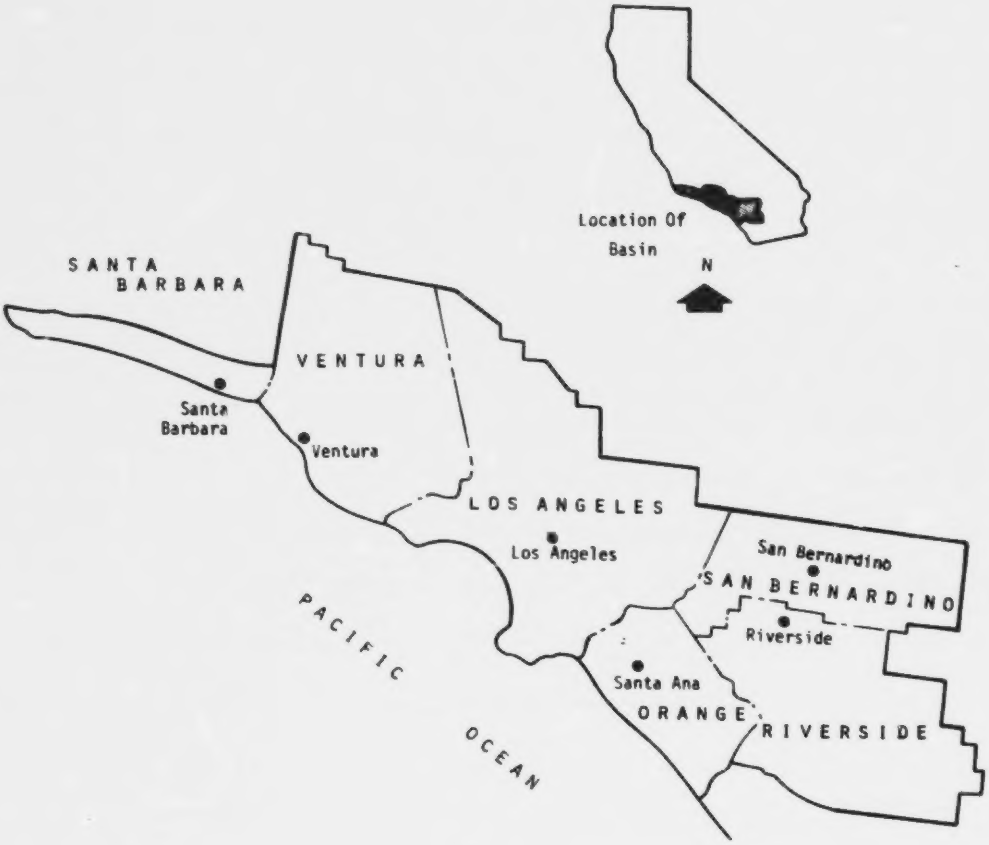
Location Of Basin
N
SANTA BARBARA
VENTURA
Santa Barbara
Ventura
LOS ANGELES
Los Angeles
San Bernardino
SAN BERNARDINO
Riverside
PACIFIC
OCEAN
Santa Ana
ORANGE
RIVERSIDE

Figure 2.1. South Coast Air Basin

Source: State of California, The Resources Agency, Air Resources Board, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, Jan. 30, 1972.

Table 2.1. Population and Land Area - South Coast Air Basin

County	County's Population in Basin - 1970	% of County's Population in Basin	Area in Basin (Mi^2)	Population Density (Persons/Mi^2)
Los Angeles	6,923,922	98.8	2,768	2,501
Orange	1,419,200	100.0	782	1,815
Riverside	320,038	70.4	1,851	173
San Bernardino	530,755	79.3	1,135	468
Santa Barbara	149,916	56.9	281	523
Ventura	376,200	100.0	1,863	202
Totals	9,717,031		8,680	

Source: State of California, The Resources Agency, Air Resources Board, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972. Based on information supplied by the State Department of Finance.

Climatically, the South Coast Air Basin can be classified as a subtropical region characterized by dry summer seasons. Although the coast can be moderately cool, the inland valleys frequently experience very hot summers. The total annual rainfall into the Basin is moderate and occurs predominantly during the winter season; often times, the summer season is completely void of any precipitation.

Wind patterns in and throughout the Basin vary as a function of both time of day and season. Typically, during the summer daylight hours, winds flow from the west, sweeping across the Basin in an easterly manner. In the evenings the predominant wind direction frequently reverses itself. Figures 2.2 and 2.3 illustrate this for a typical October day. The almost constant flow of air from the Pacific toward the coast is due to a semi-permanent high pressure center hovering over the Pacific and situated northwest of Southern California.

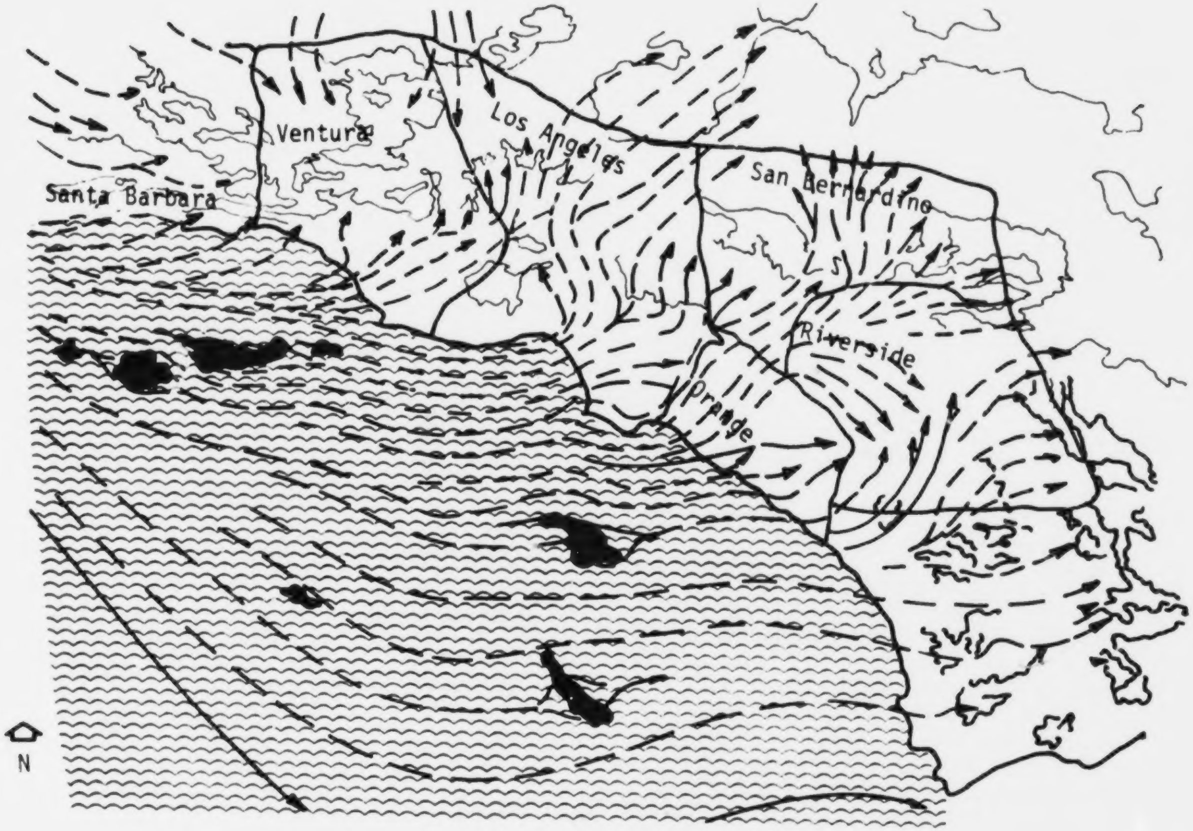
Santa Barbara
Ventura
Los Angeles
San Bernardino
Riverside
Orange
N

Figure 2.2. Air Flow Patterns - South Coast Air Basin (October 1200-1800 PST)
Source: State of California, The Resources Agency, Air Resources Board, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972.

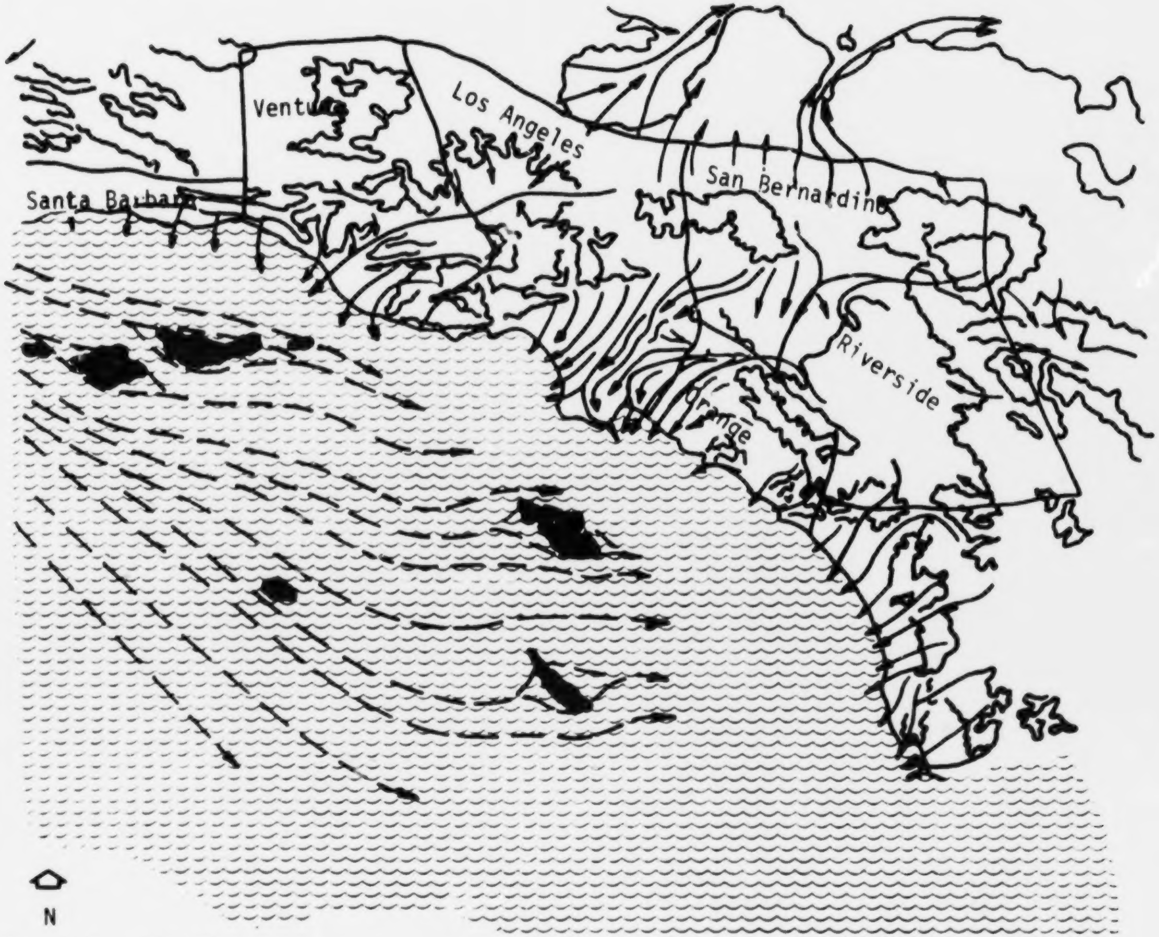
Santa Barbara
Ventura
Los Angeles
San Bernardino
Riverside
Orange
N

Figure 2.3 Air Flow Patterns - South Coast Air Basin (October 0000-0700 PST)

Source: The State of California, The Resources Agency, Air Resources Board The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972.

Table 2.2 California Population Projections - 1970 to 1980
(Millions)

	1970	1975	1977[1]	1980
Los Angeles	7.034	7.255	7.425	7.681
Orange	1.430	1.688	1.789	1.940
Riverside	.461	.499	.529	.573
San Bernardino	.689	.750	.790	.851
Ventura	.380	.451	.501	.575
South Coast Air Basin[2]	9.994	10.643	11.034	11.620
California	20.003	21.517	22.330	23.549
South Coast Basin as % of State	50.0	49.5	49.4	49.3

[1] Linear extrapolation of assumed 1975 - 1980 growth rate.

[2] The South Coast Air Basin as defined by the State "consists of all of Orange and Ventura Counties and the most populated portions of Los Angeles, Riverside, San Bernardino, and Santa Barbara Counties;" however, due to problems of data availability for anything disaggregated beyond the County, it is assumed throughout most of this report that the South Coast Air Basin is comprised of the five counties listed above.

Source: Population Research Unit, Department of Finance, Provisional Projections of California Counties to 2000, September 15, 1971 (1623 - 10th Street - Sacramento, California)

The physical features which make up and surround the South Coast Air Basin result in a very unique atmospheric environment. In fact, the geography and meteorology characteristic of the Los Angeles metropolitan region contribute to the severity of the air pollution and the difficulties of its elimination. A more detailed analysis of the meteorological factors which contribute to the air pollution in the Basin is presented in Section 2.2.2.

2.2 Problem Definition and Description

2.2.1 Air Quality in the South Coast Air Basin

Air quality measurements taken in the South Coast Air Basin show the air pollution to be a severe problem. The severity of the air pollution can be shown by at least three indices: (1) the extensive geographical area which experiences the problem, (2) the number of days per year that various established standards are violated, and (3) the number of pollutants which contribute to the problem.

Unlike areas which experience localized pollution from a limited number of point sources, the air pollution characteristic of Los Angeles is truly regional. The areal nature of the problem is the result of several factors. First, the major source of contaminants in the Basin is the automobile, which means the primary pollutants* are emitted from millions of spread out mobile sources (Figure 2.4). The low density of the region contributes to this by having thousands of miles of streets and freeways cutting around and through the 8000 or so square miles of the Basin. Finally, since the principal air pollution problem is photochemical oxidants, the primary pollutants are given the chance to diffuse before becoming involved in the photochemical reactions which ultimately generate ozone (O_3).

The geographical extent and severity of the problem is partially illustrated by Figure 2.5, which shows the levels of air pollution encoun-

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* Primary pollutants are those pollutants which are emitted directly into the atmosphere, e.g., CO, HC, NO; secondary pollutants are those which have resulted from a transformation process involving primary pollutants, e.g. NO_2, O_3.

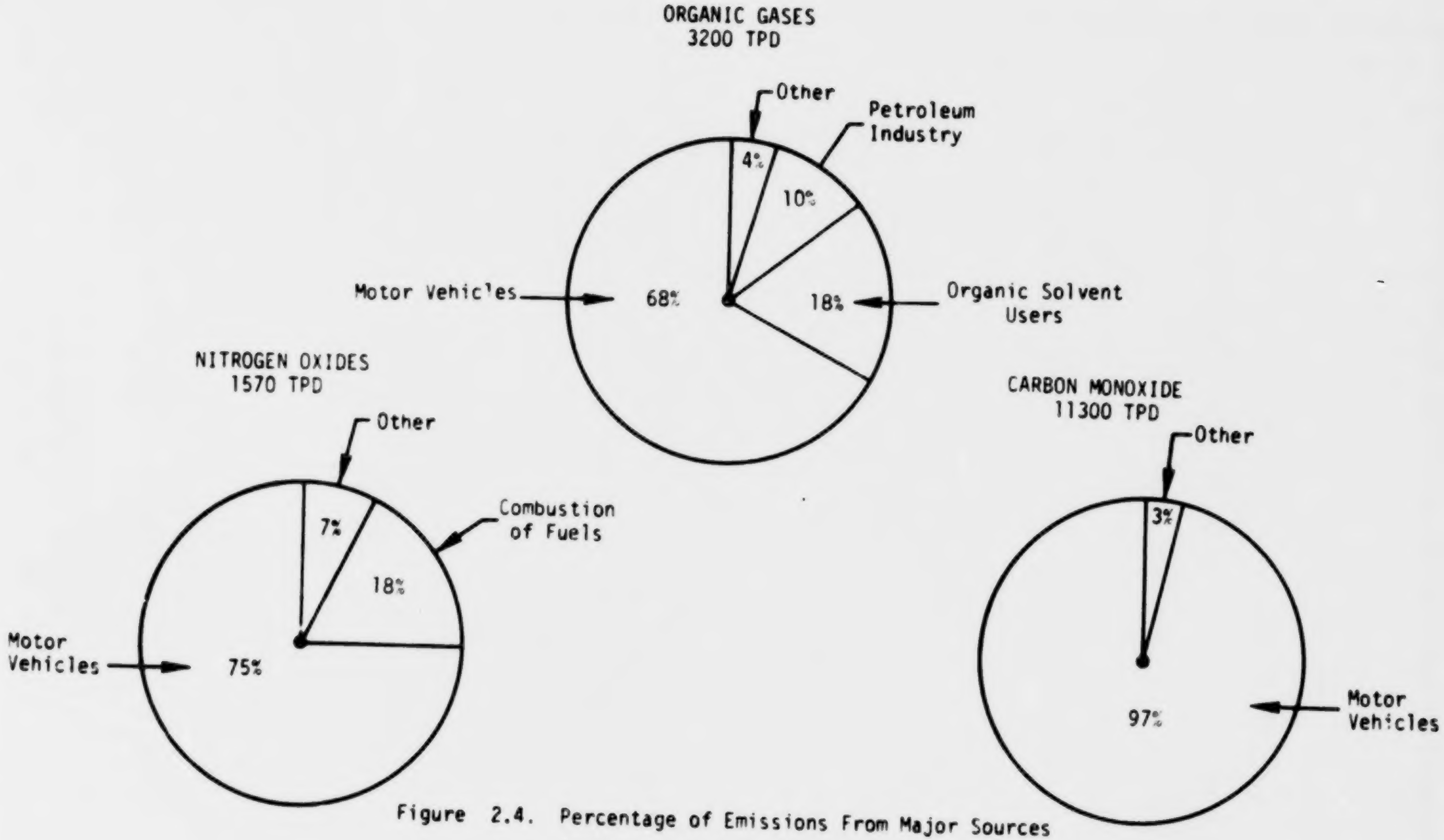
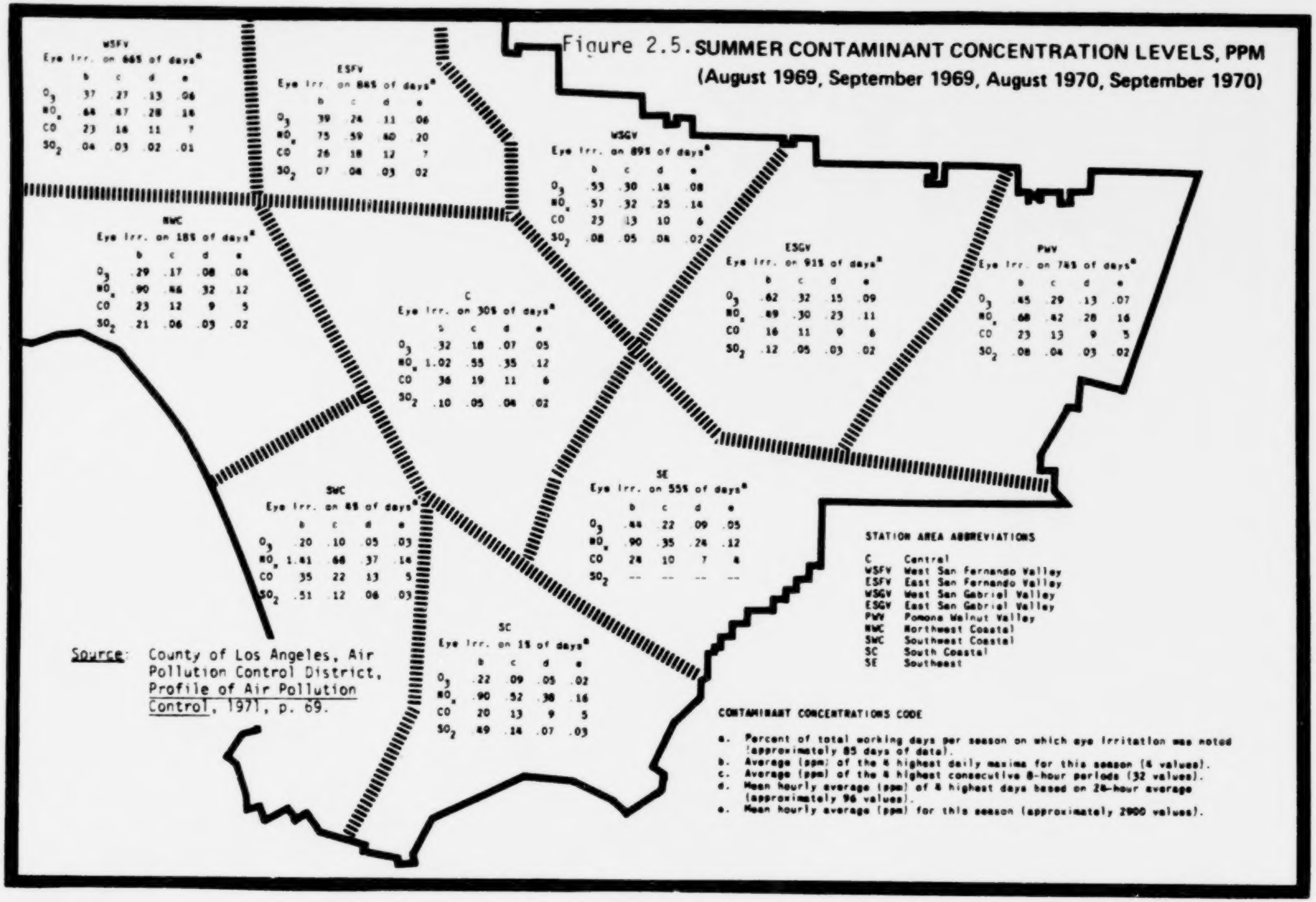


Figure 2.4. Percentage of Emissions From Major Sources in the South Coast Air Basin - 1970

Source: State of California, The Resources Agency, Air Resources Board, California Emission Inventory - 1970, July 1972, p. 45.

Figure 2.5. SUMMER CONTAMINANT CONCENTRATION LEVELS, PPM
(August 1969, September 1969, August 1970, September 1970)



WSFV
Eye Irr. on 66% of days[a]

	b	c	d	e
O_3	37	.27	.13	.06
NO_x	.64	.67	.28	.18
CO	23	16	11	7
SO_2	.04	.03	.02	.01

ESFV
Eye Irr. on 84% of days[a]

	b	c	d	e
O_3	39	.24	.11	.06
NO_x	75	.59	.40	.20
CO	26	18	12	7
SO_2	07	.04	.03	02

WSGV
Eye Irr. on 89% of days[a]

	b	c	d	e
O_3	.53	.30	.14	.08
NO_x	.57	.32	.25	.14
CO	23	13	10	6
SO_2	.08	.05	.04	.02

ESGV
Eye Irr. on 91% of days[a]

	b	c	d	e
O_3	.62	.32	.15	.09
NO_x	.89	.30	.23	.11
CO	16	11	9	6
SO_2	.12	.05	.03	.02

PWV
Eye Irr. on 74% of days[a]

	b	c	d	e
O_3	.45	.29	.13	.07
NO_x	.68	.42	.28	.16
CO	23	13	9	5
SO_2	.08	.04	.03	.02

NWC
Eye Irr. on 18% of days[a]

	b	c	d	e
O_3	.29	.17	.08	.04
NO_x	.90	.46	.32	.12
CO	23	12	9	5
SO_2	.21	.06	.03	.02

C
Eye Irr. on 30% of days[a]

	b	c	d	e
O_3	.32	.18	.07	.05
NO_x	1.02	.55	.35	.12
CO	36	19	11	6
SO_2	.10	.05	.04	.02

SWC
Eye Irr. on 4% of days[a]

	b	c	d	e
O_3	.20	.10	.05	.03
NO_x	1.41	.68	.37	.14
CO	35	22	13	5
SO_2	.51	.12	.06	.03

SE
Eye Irr. on 55% of days[a]

	b	c	d	e
O_3	.44	.22	.09	.05
NO_x	.90	.35	.24	.12
CO	24	10	7	4
SO_2	--	--	--	--

SC
Eye Irr. on 1% of days[a]

	b	c	d	e
O_3	.22	.09	.05	.02
NO_x	.90	.52	.38	.16
CO	20	13	9	5
SO_2	.49	.14	.07	.03

STATION AREA ABBREVIATIONS

C	Central
WSFV	West San Fernando Valley
ESFV	East San Fernando Valley
WSGV	West San Gabriel Valley
ESGV	East San Gabriel Valley
PWV	Pomona Walnut Valley
NWC	Northwest Coastal
SWC	Southwest Coastal
SC	South Coastal
SE	Southeast

CONTAMINANT CONCENTRATIONS CODE

a. Percent of total working days per season on which eye irritation was noted (approximately 85 days of data).
b. Average (ppm) of the 4 highest daily maxima for this season (4 values).
c. Average (ppm) of the 4 highest consecutive 8-hour periods (32 values).
d. Mean hourly average (ppm) of 4 highest days based on 24-hour average (approximately 96 values).
e. Mean hourly average (ppm) for this season (approximately 2900 values).

Source: County of Los Angeles, Air Pollution Control District, Profile of Air Pollution Control, 1971, p. 69.

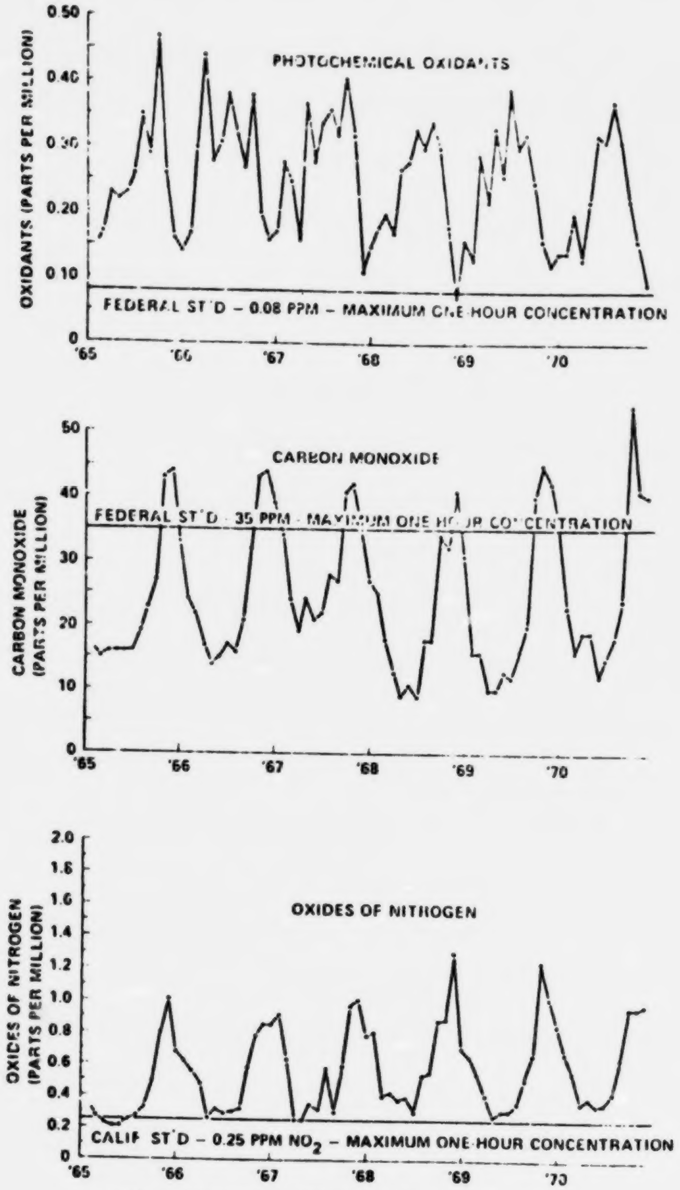
tered in various sections of Los Angeles County during the summer months of 1970. It should be pointed out that many of the worst air pollution levels were experienced in Riverside County, an area generally downwind of Los Angeles County.

The number of days on which different air quality standards is violated varies as a function of pollutant and time of year. High photochemical oxidant levels occur predominantly during the summer months whereas the CO levels are generally highest during the winter months. The seasonal variation of selected pollutants is seen by examining data compiled for the west San Fernando Valley (Figure 2.6). This valley experiences neither the best nor worst air in the Basin, and consequently, can be viewed as "typical." A more extensive breakdown of violations, which takes into account all of Los Angeles County (see Appendix B, Section I) illustrates again the regional nature of the problem.

Another index for air pollution severity is the number of contaminants which violate established standards. Nearly all national ambient air quality standards were violated during 1970. Sulfur dioxide (SO_2), which presently is of relatively minor concern, did not violate the primary standard (based on public health), but did exceed the secondary standard (based on public welfare).

2.2.2 Contributing Factors to the Problem

There are a variety of reasons why air pollution has grown to be such a problem in the South Coast Air Basin. Hopefully, by understanding the evolution of the problem, strategies can be developed which will attack the root of the problem. This brief synopsis of several critical contributing factors is presented only to serve as a foundation on which to better understand the rationale behind the development of various control



NOTE: THE FEDERAL STANDARD IS 0.05 PPM NO_2
ANNUAL ARITHMETIC MEAN

Figure 2.6. Major Air Pollutants - Monthly Maximum Hourly Averages
West San Fernando Valley (Monitored in Reseda) 1965- 1970.

Source: Branch, M. C., and E. Y. Leong (eds.), Research Investigation-Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972, p. 6.

strategies. Although discussed separately, each contributing factor is directly related and inter-related to the other factors. It is the combination of all of these factors and others which has led us to the problem.

Growth in Population, Motor Vehicles, and Gasoline Consumption

One of the most obvious reasons for increased air pollution is physical growth; in the time period since World War II, Southern California has sustained a rapid growth rate in people and their accompanying motor vehicles. Even more important has been the more rapid increase in fossil fuel consumption for motor vehicles. This latter fact is most critical to the generation of air pollution.

The California State Department of Finance periodically updates its forecasts for population growth trends within the State. Its most recent provisional forecast for the South Coast Air Basin (Table 2.2) reflect several changes which have resulted recently:

- A rapid decline in women's fertility rates in all ages, especially from 1963-1968.
- A decreasing net migration which in 1970-71 was 10% of that experienced during 1964-65.

As a result of these phenomena, both findings of the 1970 census, all population forecasts have been revised downward. Ideally, this latest data should be used for projecting motor vehicles and gasoline consumption. In some cases this has been done, in others it has not.

Projections of motor vehicle registration by county and vehicle type are made by the State Department of Motor Vehicles using population estimates provided by the Department of Finance. Unfortunately, their most recent projection report(70) was made in March, 1970 using pre-1970 census information; consequently, the numbers in the report are likely to be high.

The Department of Motor Vehicles is currently updating its motor vehicle registration forecasts utilizing the more recent population figures. However, their results were incomplete and unavailable to us for this study.

In an attempt to estimate air pollution emissions, several groups have made projections of gasoline consumption. Information on the volume of gasoline sold statewide is available from the State Controller's Office, which collects a gas tax of 7 cents per gallon for gasoline sold within the State. Both the California Air Resources Board (Figures 2.7 and 2.8) and the Los Angeles County Air Pollution Control District have made projections of gasoline consumed to 1990. The techniques used by both organizations are very similar; essentially, the projections are made by linear correleation of "past performance." Using the population estimates or population and motor vehicle data, gasoline consumption is projected by a linear correlation procedure. The projections made by these two groups is somewhat questionable for two reasons:

1) the population estimates used for their most recent projections was pre-1970 census data; as discussed previously, these figures are higher than more recent forecasts.

2) the projections assume that population and/or motor vehicle registrations are the only independent variables which account for gasoline consumption; there is strong indication that other variables need to be considered.

Recently, a study conducted at UCLA incorporated the latest population estimates for California, to project both motor vehicles and gasoline consumption (Figure 2.9 and 2.10). The methodology used was a time series, multiple regression technique. In their report, a number of independent variables were tested to determine their contribution to explaining vehicle

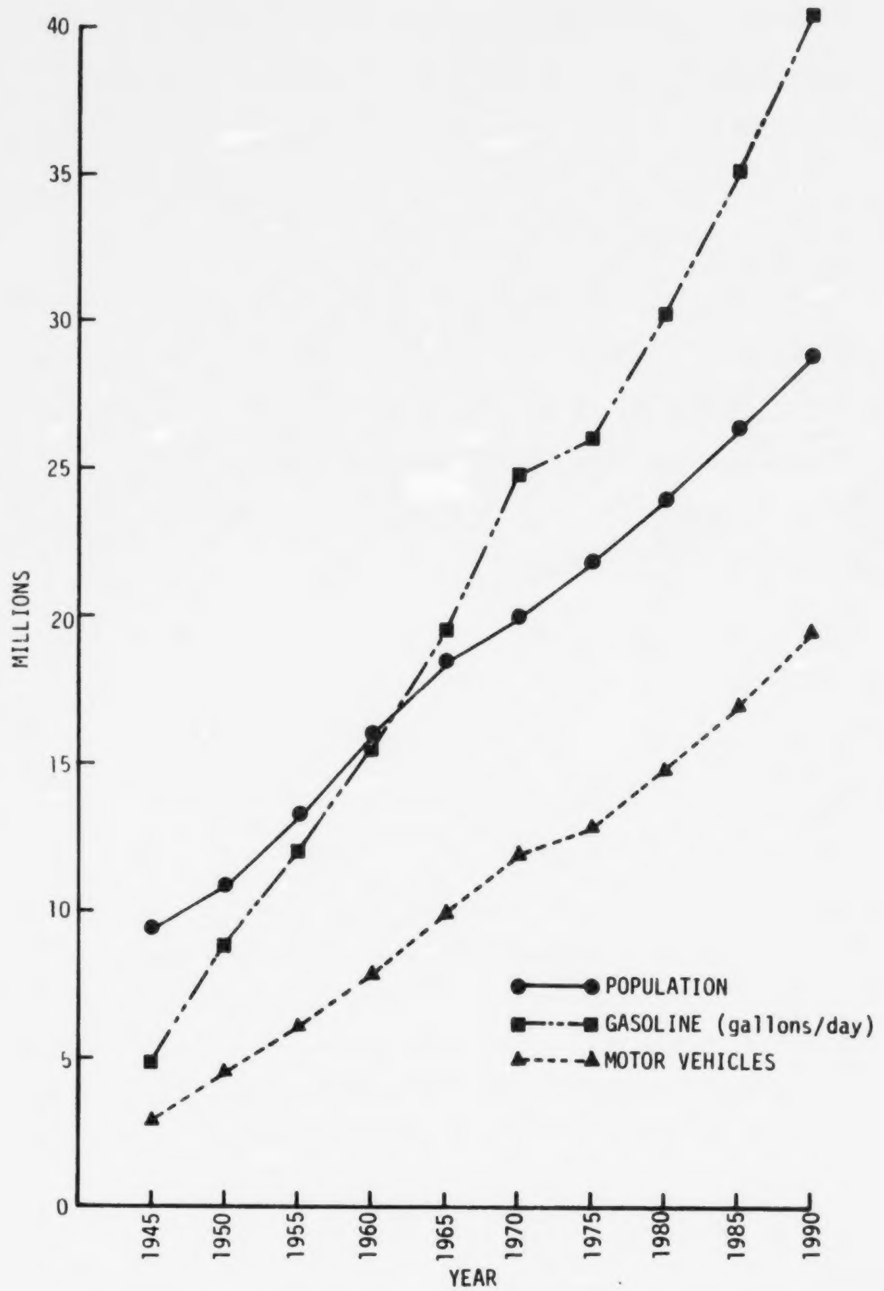


Figure 2.7 Population, Motor Vehicles, Daily Gasoline Consumption - State of California

Source: California Air Resources Board, Memo dated March 16, 1972.

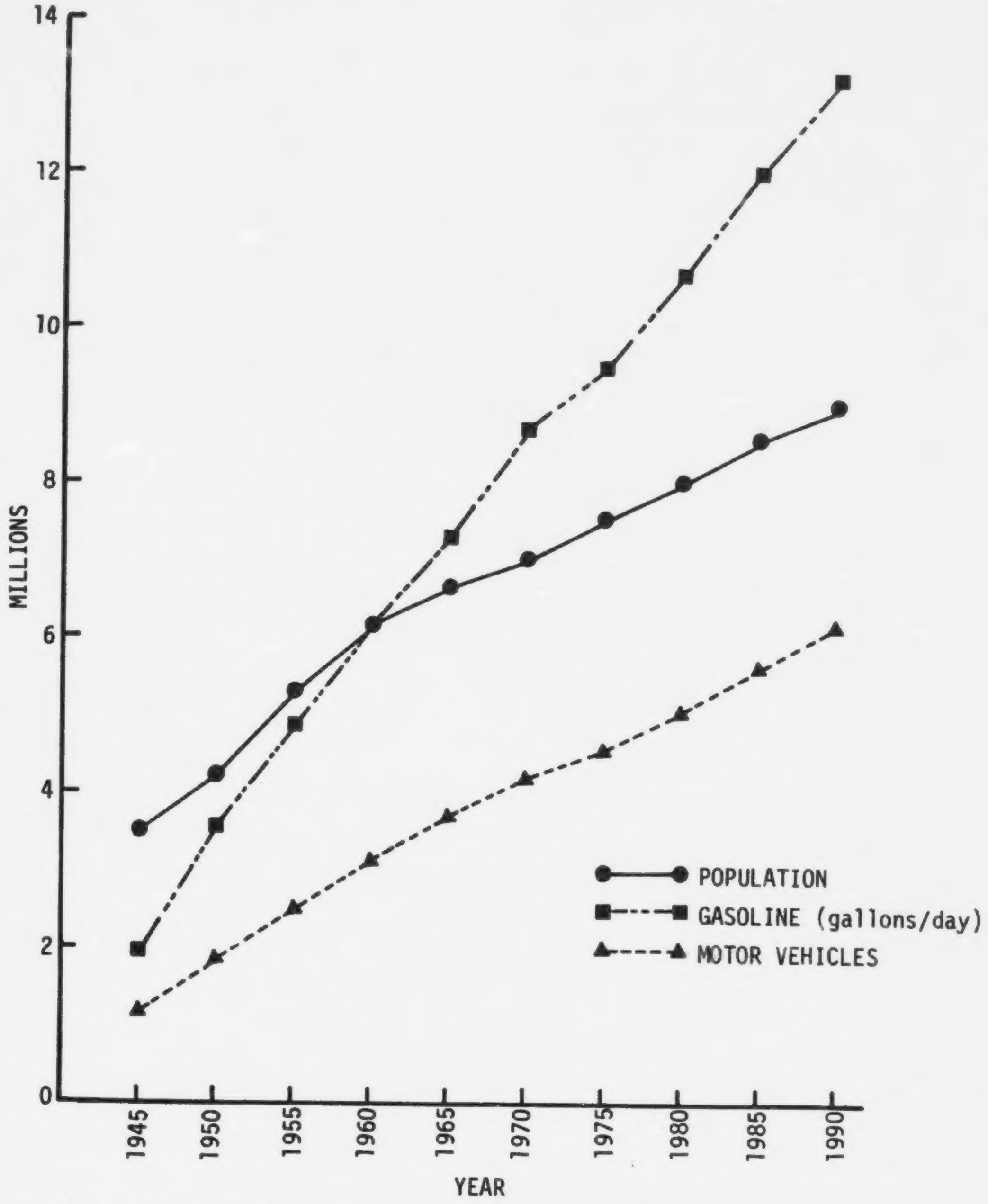


Figure 2.8 Population, Motor Vehicles, and Daily Gasoline Consumption - Los Angeles County

Source: California Air Resources Board, Memo dated March 16, 1972.

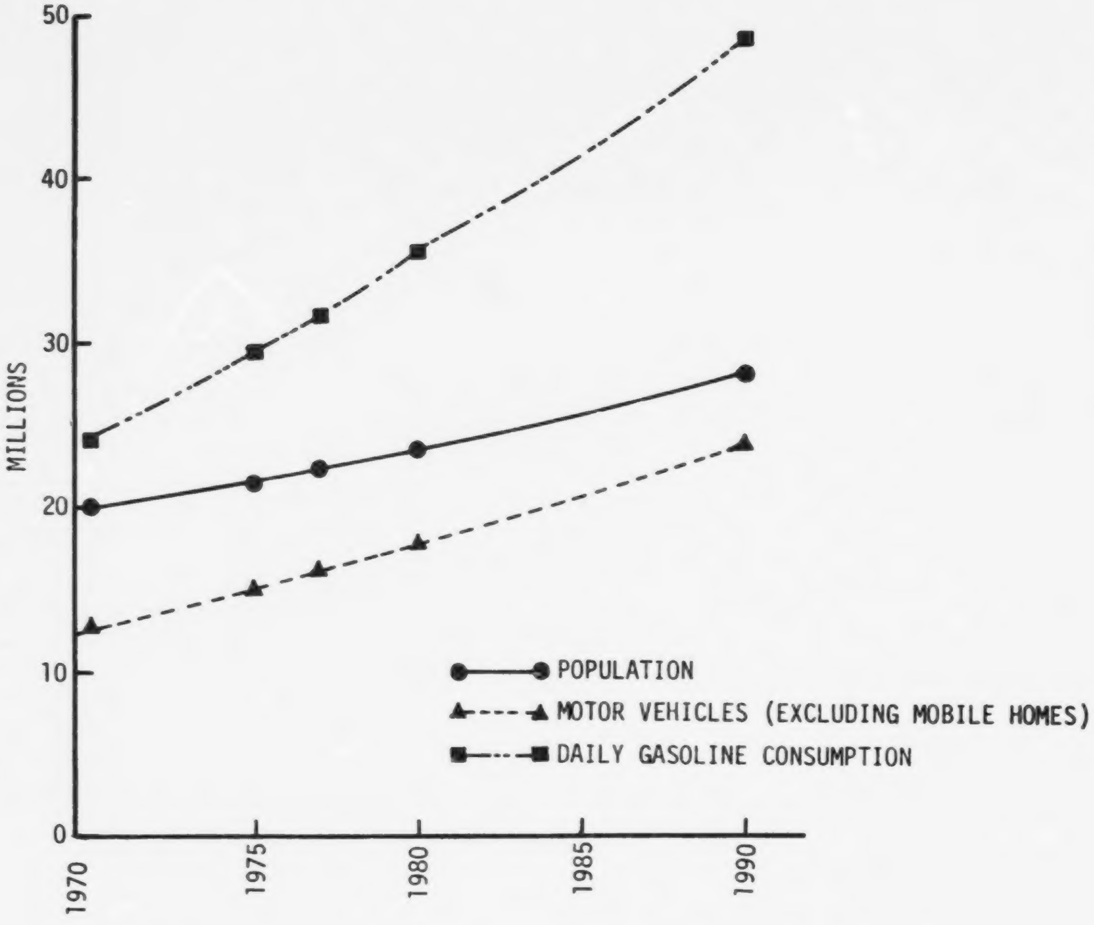


Figure 2.9 State of California Projections for Population, Motor Vehicles, and Gasoline Consumption (1970 - 1990)

Source: Branch, M. C. and E. Y. Leong (eds.), Research Investigation - Air Pollution and City Planning, Environmental Science and Engineering, UCLA, 1972, Appendix G.

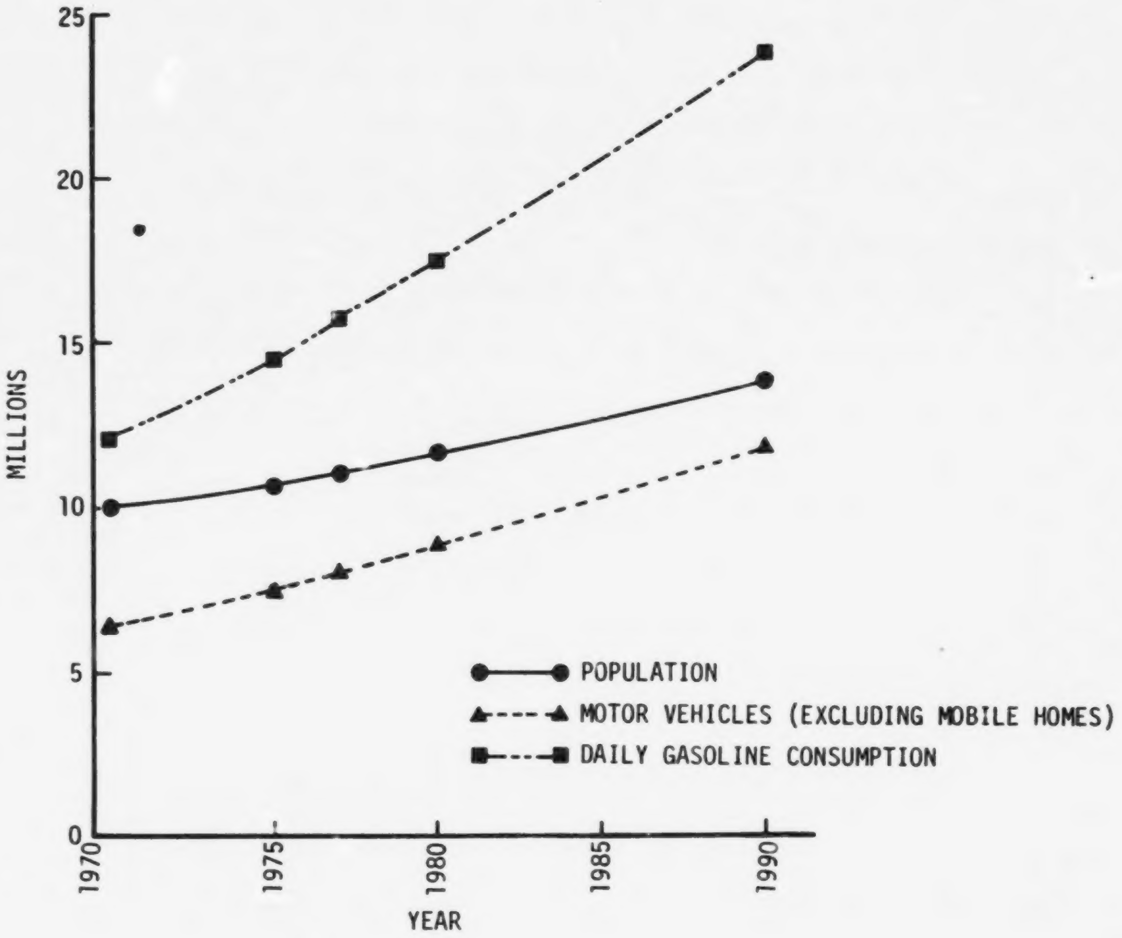


Figure 2.10 South Coast Air Basin Projections for Population, Motor Vehicles, and Gasoline Consumption (1970 - 1990)

Source: Adapted from Branch, M. C. and E. Y. Leong (eds.), Research Investigation - Air Pollution and City Planning, Environmental Science and Engineering, UCLA, 1972, Appendix G.

registrations and gasoline consumption. The variables tested included total state population, personal income in current dollars, price adjusted personal income, miles of freeway completed and simple time correlation. Of the variables tested, total population and price-adjusted income were the most significant terms for projections of motor vehicles and gasoline consumption. Figure 2.10 shows the results of such a projection for the South Coast Air Basin. It is recommended that groups making forecasts of gasoline consumption or motor vehicles use the procedure developed by the UCLA study team or a similar one which incorporates economic variables into the analysis.

The UCLA projections were made for total motor vehicles only (excluding mobile homes). An approximate breakdown by specific type of vehicles can be made by adjusting the 1970 projections by the Department of Motor Vehicles and assuming the same relative proportion of vehicle types given in their report.(70)

Since the rate of growth in gasoline consumption is the most rapid of the growth rates discussed here and since air pollution is most directly related to its consumption, any control strategies which are likely to have a significant impact must address the issue of growth. This is especially true for long range solutions, but very important in the short run as well. Concurrent with the increased use of gasoline comes significantly higher vehicle miles traveled and hence, more air pollution within the Basin. This growth will be discussed later in the analysis of the transportation data base.

Meteorological Factors

As alluded to briefly, the meteorological and geographical characteristics of the South Coast Basin contribute to the air pollution situation. Various scientists have referred to the Basin as a "huge smog chamber." The range of mountains, low inversions and wind speeds, and intense sunlight are all factors which contribute directly to the formation of photochemical smog. The lack of appreciable amounts of precipitation, especially during the summer months when oxidants are most intense, helps to perpetuate the problem. An examination of meteorological data compiled by the LAAPCD shows the air pollution "potential" of the Basin (Table 2.3).

In an attempt to correlate high ozone concentration values to various meteorological parameters, Trijonis(83) found that the variables which correlated highest to ozone concentrations were solar radiation intensity, temperature, maximum mixing height, and temperature gradient. These factors have to be carefully considered in the development of control strategies which alter the temporal distribution of pollutants, e.g., staggered work hours. Partial correlation coefficients derived from his multiple regression analysis are presented in Table 2.4.

Transportation Systems

The rapid growth in motor vehicles has been accompanied by a high growth rate in freeways and surface streets. Agencies which plan for transportation have improved service and flow facilitating more individual travel and increased vehicle miles traveled (VMT). With the emergence of life styles more dependent on private automobiles for personal mobility and with more leisure time for travel, VMT figures have steadily risen. Figure 2.11 illustrates the extremely rapid growth in freeway miles within the South Coast Basin.

Table 2.3. SUMMARY OF METEOROLOGICAL DATA - LOS ANGELES COUNTY

	Average (1950-1970)	1964	1965	1966	1967	1968	1969	1970
I. Number of Days Inversion Base								
Height in the Following Ranges (feet above mean sea level)								
Surface	134	138	134	141	136	142	134	120
Less than 1500 feet	204	212	197	210	204	207	197	211
Less than 2500 feet	261	269	241	274	265	260	252	271
II. Number of Days with Maximum Mixing Height ≤ 3500 feet	192	194	171	205	191	184	198	205
III. Number of Days Average 0600 - 1200 PST Wind Speed ≤ 5.0 MPH	237	230	258	299	273	300	275	273
IV. Number of Days Inversion Base Height ≤ 1500 feet, Maximum Inversion Height ≤ 3500 feet and Average 0600-1200 PST Wind Speed ≤ 5.0 MPH	91	97	84	106	94	103	83	108
V. Precipitation								
Total for year (inches)	14.68	---	---	12.91	23.66	7.58	26.32	16.54
Number of days with more than a trace	36	---	---	19	36	32	40	31
VI. Wind (MPH) -								
Mean Hourly Wind Speed Average	6.2	---	---	5.3	5.2	5.1	5.3	5.4
0600-1200 PST Wind Speed	5.1	---	---	4.5	4.5	4.3	5.1	4.6

SOURCE: County of Los Angeles, Air Pollution Control District, Data Processing and Meteorology Section - Technical Services Division, Annual Summary - Meteorology, Air Pollution Effects and Contaminant Maxima - Calendar Years 1966-1970.

Table 2.4. Ozone Related Weather Factors

Weather Variable	Typical Partial Correlation Coefficient
Average solar radiation intensity in downtown L.A. from 9:00 a.m. to 1:00 p.m. Civic Time (Langleys per hour)	0.7
Maximum daily temperature in downtown L.A. (°F)	0.7
Maximum mixing height in L.A. as calculated by the APCD from temperature readings (feet)	0.6
Average 9:00-12:00 PST wind speed (miles per hour)	0.2
Minimum hourly relative humidity in downtown L.A. (percent)	0.2
Inversion strength, difference in temperature at base and top of inversion at 7:00 PST (°F)	0.4
7:00 PST pressure gradient between L.A. International Airport and Palmdale (millibars)	0.2
Daily change in pressure gradient between L.A. International Airport and Palmdale (millibars)	0.1
7:00 PST inversion base height (feet)	0.1

Source: Trijonis, J. C., An Economic Air Pollution Control Model Application: Photochemical Smog in Los Angeles County in 1975, Ph.D. Thesis, California Institute of Technology, Pasadena, California, 1972, pp. 166-167.

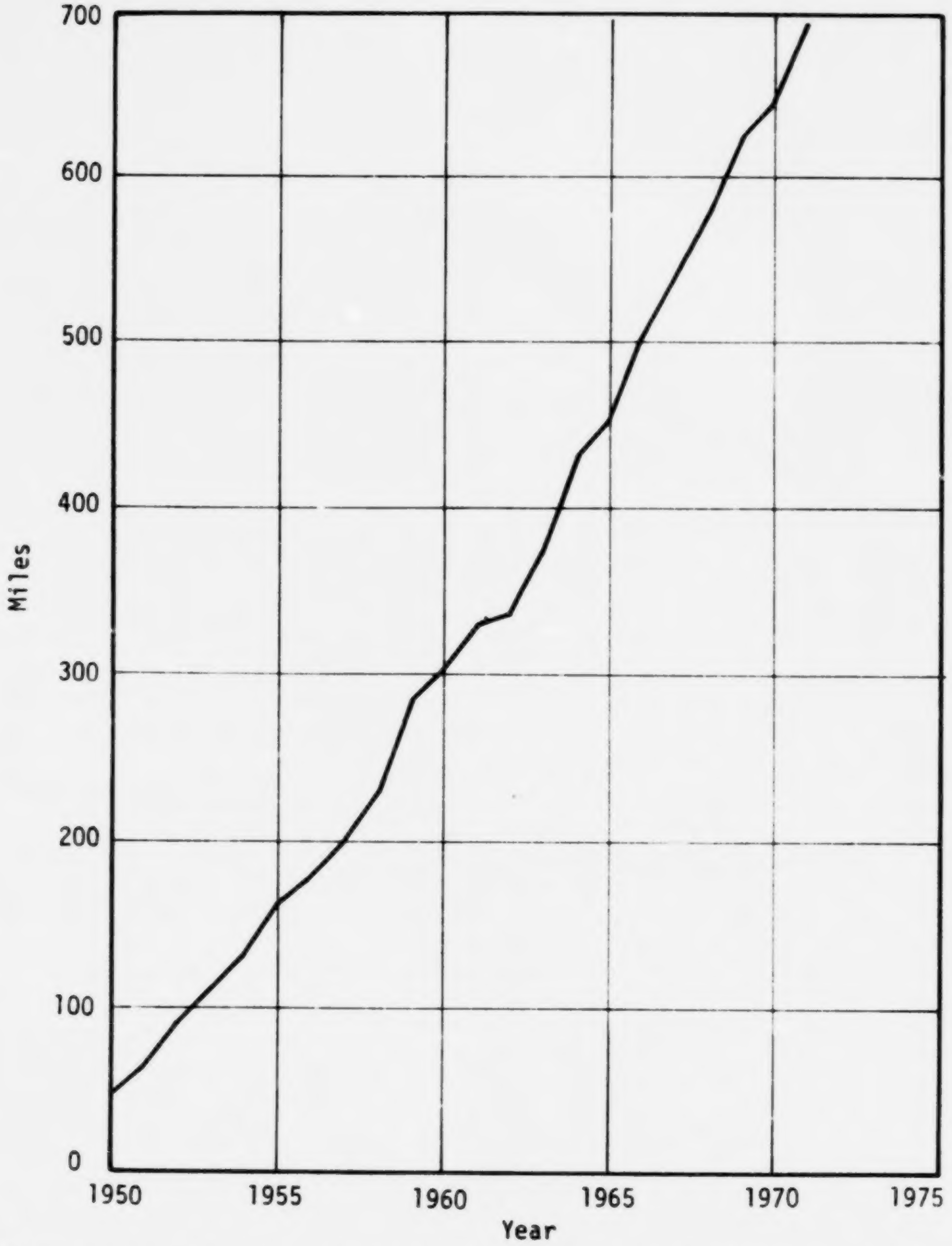


Figure 2.11. Miles of Freeway, Five-County Los Angeles Metropolitan Area (Los Angeles, Orange, Ventura, Riverside, San Bernardino).

Source: Branch, M. C. and E. Y. Leong (eds.), Research Investigation - Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972, p. G-12.

The addition of each mile of freeway has resulted in higher VMT. First, from motorists travelling extra distances to use the freeways, realizing the quickest route is not necessarily a straight line. Then also, by the many additional and longer trips which probably would not have been made without the improved access made possible because of the extensive freeway system.

Economic Growth

Directly responsible for much of the growth in number of motor vehicles and gasoline consumption has been the steady economic growth experienced in the Los Angeles region. With increased personal incomes and a lower percentage of income being devoted to transportation needs, private automobile travel has become relatively inexpensive.

Currently, the fraction of personal income devoted to transportation is 9 percent, as shown in Figure 2.12. Over the past two decades, the percentage of one's personal income necessary to purchase an automobile has slowly but steadily decreased. This has resulted in private automobile travel becoming accessible to virtually all but the very poor. Affluence and prestige have prompted the purchase of many autos; however, it is the existing land use patterns and inadequacy of public transit services which have promoted the almost complete dependence on automobiles for travel in the South Coast Air Basin.

The introduction of safety features and more advanced pollution control devices will increase the cost of automobiles. However, this increase is not likely to substantially affect the number of vehicles purchased or the amount of fuel consumed.

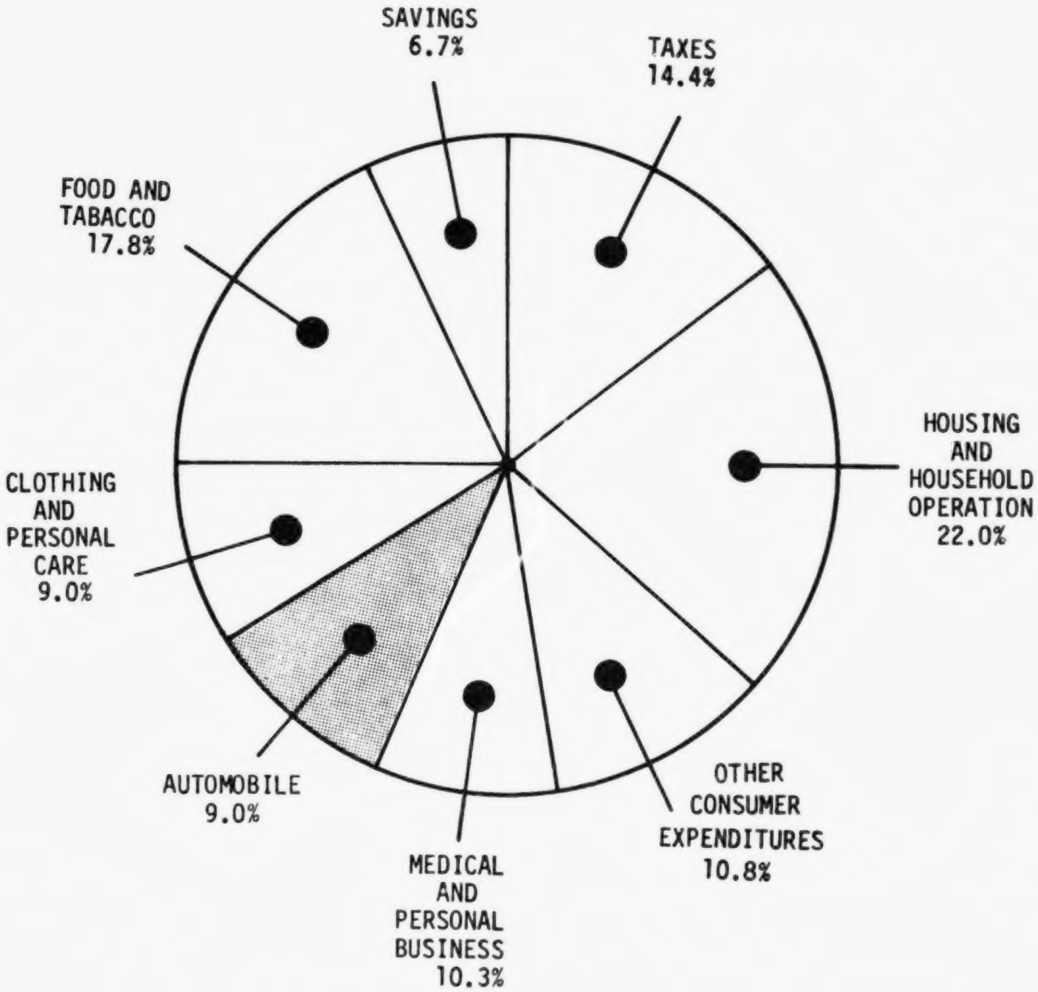


Figure 2.12. Personal Income Expenditures

Source: Motor Vehicle Manufacturers of the U.S., Inc., 1972 Automobile Facts and Figures, 1972, p. 68.

The relatively small percentage of personal income now devoted to transportation is one of the reasons pricing schemes to discourage driving are not very effective. Similarly, the percentage of income devoted to gasoline purchases is only a fraction of the total transportation costs which are incurred. Therefore, strategies such as doubling the price of gasoline or applying some form of "emissions tax" cannot be expected to significantly reduce travel. A more thorough examination of pricing schemes and their probable impacts is presented later.

Along with increased affluence, an increase in leisure time has become available to many people. This extra available time has resulted in extra recreational and shopping trips, which in turn, have contributed to the increased VMT figures.

Economic growth for the Basin residents is directly correlated to economic activity in the industrial and business sectors. In fact, in one study it was felt economic activity could be used to assist in forecasting pollution emissions.(57) Economic projections were made with the following assumptions:

1) Pollutant emissions are related to the amount of economic activity generated in an area and this relationship can be measured and projected;

2) Economic activity in appropriate detail can be projected more confidently than can the pollutant emission quantities themselves;

3) The product of the projected relationships and economic activity yields an approximation of the pollutant emissions; and

4) A projection of the economy of each region in the appropriate industrial detail will yield an economic framework within which the impact of proposed pollution control measures on the economic future of the area can be calculated and evaluated.

A summary of the economic growth projections for the Los Angeles region as well as other parts of the country are given in Appendix C. Also presented in this appendix is some data showing recent economic growth trends within the region. This growth would probably correlate very well with the growth in air pollution problems.

Land Use Practices

Growth in population, transportation networks and economic indices are all related to and often major determinants of land use practices. On the other hand, it is these land use practices dictated by economic forces, which contribute to the many miles driven within the Basin. It has long been realized that long range solutions to the air pollution problem must rely on better land use planning. In spite of an early recognition to the land use problem, action on the State level has been very slow.

The continued trend toward low density development with marked separations of land uses by specific categories has helped promote the need for divergent travel requirements. Present development patterns in many of the areas around the Basin are following the same patterns. Bedroom communities continue to be developed in portions of the San Fernando Valley, Ventura County, the undeveloped portions of Los Angeles and Orange Counties. Little if any thought is given to where the residents will work and/or how long the commute trip will be.

2.3 The Prospects of Achieving the Federal Ambient Air Quality Standards in the South Coast Air Basin

The severity of photochemical smog in the South Coast Air Basin has resulted in numerous studies of the problem. In fact, much of our knowledge concerning modern air pollution is the result of studies originating in the Los Angeles region. Every aspect of the problem, whether it be technical, economic, political, or social in nature, has been the subject of a detailed analysis. This section attempts to review very briefly a few of the groups who have assessed the Los Angeles air pollution situation and commented on the prospects of attaining the promulgated air quality standards, especially the 0.08 ppm photochemical oxidant standard.

The Technical Advisory Committee of the California Air Resources Board

> .."because of such factors as mass of population and numbers of sources, some of the standards can be reached only by major changes in the mode of life...it is the reduction of emissions into the atmosphere which ameliorates air pollution, not the simple act of legislating a strict air quality standard... It is probable that an oxidant standard of 0.1 ppm (California's air quality standard for oxidants is 0.1 ppm) will not be reached in Los Angeles by implementing programs designed solely to limit emissions from sources, now anticipated on the basis of existing growth patterns...the maximum hourly average oxidant values in Los Angeles will probably not be below 0.3 ppm by 1980, will not be below 0.2 ppm by 1985, and cannot be expected to reach 0.1 (9)."
>
> September 1970

Environmental Quality Laboratory - California Institute of Technology

> "We recognize that the South Coast Air Basin in California is faced with a uniquely difficult air pollution control problem. Because of its special meteorology and topography, and the enormous rate of consumption of fossil fuels, even the best technology likely to be available in this decade would not reduce the average number of days per year on which State air quality standards on photochemical oxidants are violated below a lower bound of 10-15 days (46)."
>
> Fall, 1972

Environmental Science and Engineering Program -
University of California, Los Angeles

> "Even if automobile emissions are reduced as required by the Clean Air Act of 1970, but present trends in the use of fossil fuels continue, the ambient air pollution levels...will not be reached by 1985 and most probably not by 1990."(93)

Spring,1972

A. P. Altshuller, et al, Environmental Protection Agency, Research & Monitoring Office

> "Complete control of automotive emissions, other combustion sources, and organic solvents in the Los Angeles basin still is not likely to reduce hydrocarbons to the level of air quality for hydrocarbons desired... If all other hydrocarbons except ethane and propane were completely eliminated and nitrogen oxides reduced by 90%, background ozone levels might be formed."(2)

October, 1971

A. P. Carlin[a] and G. E. Kocher, The Rand Corporation

> "If, for example, the NO_x standards required by the Clean Air Amendments of 1970 are imposed in 1975 on 1976 model vehicles, and if this were the last tightening required to meet the air quality standards, these standards would be met about 1985. Given that used vehicle controls may be forthcoming, but that the requirements of the Clean Air Amendments may not prove sufficient, the mid-1980's are probably a safe lower bound for achievement...of the air quality standards... (Given) more costly or politically difficult actions (are required, the standards)...may not be reached until well into the 1990's, or even later."(21)

May, 1971

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[a] Currently Director of Implementation Research Division, Environmental Protection Agency.

3.0 CONTROL STRATEGY DEVELOPMENT

This chapter reviews much of the air pollution control activity being carried out in the South Coast Air Basin (and California). It lists the control strategies which were evaluated during the study and presents the rationale for the proposed control strategy.

The California Air Resources Board has long been engaged in air pollution control. Attempts were made to follow the results of many of their ongoing programs and to develop a control strategy which would, as much as possible, be consistent with their goals and objectives.

As seen from the previous chapter, the most severe problem experienced within the Basin is photochemical oxidants. The levels experienced occasionally exceed the promulgated standard of 0.08 ppm oxidant by 600-700 percent. Controlling oxidants implies controlling the sources of reactive hydrocarbons and oxides of nitrogen.

Any control strategy which would reduce the oxidant to 0.08 ppm would easily allow for the attainment of the CO and NO_2 air quality standards as well. Due to the regional nature of the problem, it is inconceivable in the foreseeable future, that oxidants would not be the limiting constraint for achieving the air quality standards.

3.1 California State Implementation Plan Review

The implementation plan proposed by the California Air Resources Board (CARB) for achieving the federal ambient air quality standards was probably the most severe set of strategies proposed nationally. For several of the key elements in their proposal, the CARB would need to obtain additional legislation. Nevertheless, assuming full implementation of the submitted plan, several portions of California, including the South Coast Air Basin, fall substantially short of the air quality goals set forth. In essence, the State's position is "the achievement of all of the national air quality standards will be very difficult, if not impossible..." (79).

California has pioneered much of the work in air pollution control. Through the 1974 model year cars, California has a more stringent motor vehicle emission control program than the Federal government. Due to the severity of the air pollution problem, however, all currently planned or projected programs are inadequate to reduce the automotive emissions to the required levels. This section briefly reviews the California strategy for attempting to achieve the national ambient air quality standards. Primary emphasis is placed on emissions from mobile source categories since they presently account for the largest share of the problem.

The largest reductions in emissions to be gained in California over the next five years will come from continuation and extension of their "current motor vehicle control programs." Under the ARB's current programs are requirements for both new and used motor vehicles.

The key elements of California's control program for new motor vehicles include:

- Crankcase emission control requirement for all new gasoline-powered vehicles.
- Exhaust emission standards for all vehicles, both diesel and gasoline powered, becoming increasingly stringent through the 1975 model car.

- Evaporative fuel emission standards for all post-1969 gasoline-powered light-duty vehicles and post-1972 heavy-duty vehicles.

- Assembly line testing of light-duty vehicles destined for the California market to show compliance with the established standards. Testing is to cover 25 percent of the 1972 models, 50 percent of the 1973 models sold prior to January 1, 1973 and 100 percent thereafter.

The elements which make up California's used motor vehicle control program are summarized below:

- Installation of crankcase emission control devices in the most populous counties upon change of ownership.

- Installation of exhaust control devices on 1955-65 light duty vehicles upon change of ownership or initial registration in California. This program was initiated in the South Coast Air Basin on September 1, 1972 and will be extended to the San Francisco area on March 1, 1973.

- Installation of an exhaust control system which significantly reduces the oxides of nitrogen in 1966-1970 model vehicles upon change of ownership or initial registration in California. This program will be initiated in Riverside County on February 1, 1973 and in the other portions of the South Coast Air Basin on April 1, 1973. Starting on July 1, 1973, all other subject vehicles, unless already fitted or exempted shall be fitted.

In addition to the motor vehicle control programs, the State is engaged in a variety of other activities which are also aimed at reducing motor vehicle emissions. Other components of their ongoing control program are:

- Limitation of the degree of unsaturation of gasoline sold in the South Coast Air Basin, and regulation of the volatility of gasoline sold thorughout the State.

- A tax exemption for gaseous fuels from the fuel tax when such fuels are used in motor vehicles equipped with approved conversion systems.

- Provision of funds to support public transportation through a gasoline sales tax.

- Testing of incentive programs to encourage more extensive use of public transportation and car pools by commuters.

- Evaluation of the air quality impact from traffic flow improvements on the freeways.

- Continuation of an air pollution research program.

- Review of the effectiveness of the States' motor vehicle emission control program by:

  - Exhaust emission testing of motor vehicles at two Los Angeles sites.

  - Requiring a Certificate of Compliance from authorized inspection stations upon transfer of ownership for used cars.

  - Enforcement of the California Vehicle Code which prohibits the emission of excessive smoke in vehicle exhaust.

  - Conducting random roadside checks of 1966 and later vehicles for exhaust emission abnormalities.

Effective implementation and enforcement of the many phases of the State's ongoing motor vehicle control program will result in a substantial decrease in automotive emissions. The impact of these programs on the number of days per year various air quality standards are exceeded should be significant. However, there will still be many days per year the standards will be violated. In an attempt to further reduce the automotive emissions, California proposed in their Implementation Plan to investigate the feasibility of additional control strategies. Especially in areas of severe air pollution, such as Los Angeles, the following measures were and are being considered:

- Controlling vehicular emissions from sources currently exempt, e.g., motorcycles.

- Mandatory motor vehicle inspection and maintenance.

- Retrofitting 1966 through 1969 vehicles with evaporative emission control devices.

- Minimizing and controlling gasoline spillages and vapor losses from service station fueling operations.

- Decreasing motor vehicle usage.

- Converting portions of the automobile population to the use of gaseous fuels.

- Requiring local planning agencies to develop land use plans which include measures to minimize or prevent air pollution.

- Requiring the use of low-lead or unleaded gasoline.

The more rapid attainment of air quality objectives depend largely on the success or failure of implementing the above mentioned programs. The degree of improvement obtainable from any of these programs is a function of several variables: 1) the number of motor vehicles affected, 2) the extent to which emissions are improved and/or auto usage decreased, and finally, 3) the extent to which the reduction in emissions affects ambient air quality.

Specifically, the Air Resources Board proposed five key strategies oriented at controlling automotive emissions beyond the current motor vehicle control program:

1) A program of periodic vehicle inspection and mandatory maintenance.

2) A program to require retrofit control of the fuel evaporative emissions from 1966 through 1969 model vehicles.

3) A program to convert one-third of the gasoline powered vehicles to use gaseous fuels.

4) Measures to reduce motor vehicle usage through car pooling and work schedule changes. A goal of reducing traffic by 20 percent was set.

5) Steps to significantly reduce the evaporative losses from gasoline marketing operations.

Despite proposing several strategies which would have a significant impact on the life styles of the Basin's residents, the plan was unable to reach the goal established. The plan projected that by 1977, the maximum oxidant level would still be 0.15 ppm or almost two times the promulgated standard.

Figures 3.1 through 3.3 summarize the critical strategies proposed in the California Implementation Plan. It will be shown later that the prospect of implementing these critical strategies in the near future, when they are both needed most and most effective, is low. A variety of implementation obstacles impedes progress toward achieving the standards.

A review of the reductions claimed by the ARB shows several of them to be highly optimistic. Table 3.1 lists the reductions attributable to a periodic inspection and maintenance program. It appears the high reductions claimed by the ARB were the result of several factors: 1) assuming the initial reductions attainable from inspection and maintenance programs (see Section 4.1 for details of several State studies on the subject), and 2) the lack of Federal guidelines during the plan preparation for what reductions should have been claimed. On this latter point, the most recent EPA guidelines for reductions from inspection and maintenance are presented in Table 3.2. In general, the lower results are attributable to correcting for deterioration throughout the year between inspection and tune-ups.

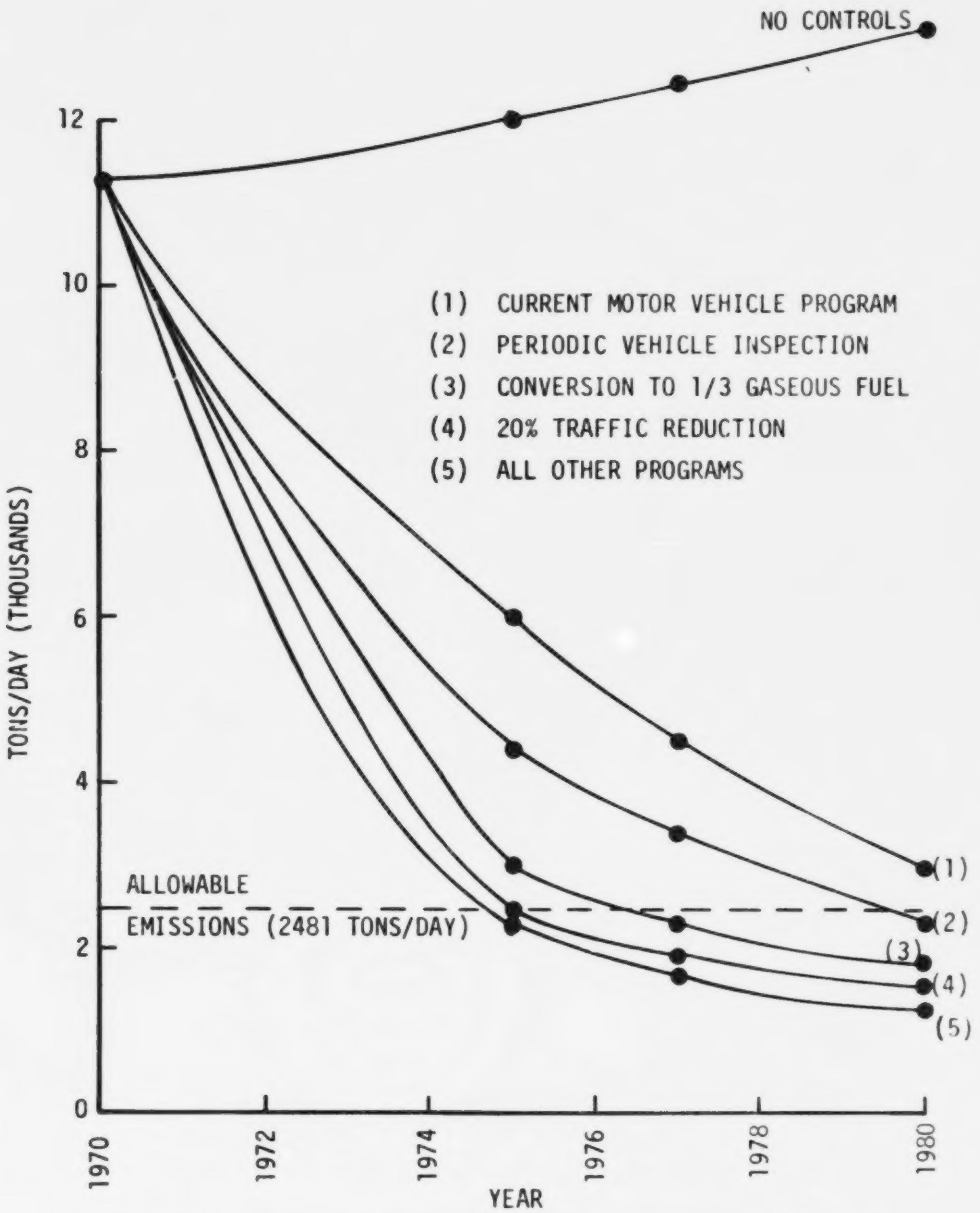

Figure 3.1. Proposed California Air Resources Board Strategy Carbon Monoxide Emission Controls (1970 - 1980).

Source: California Air Resources Board, February, 1972.

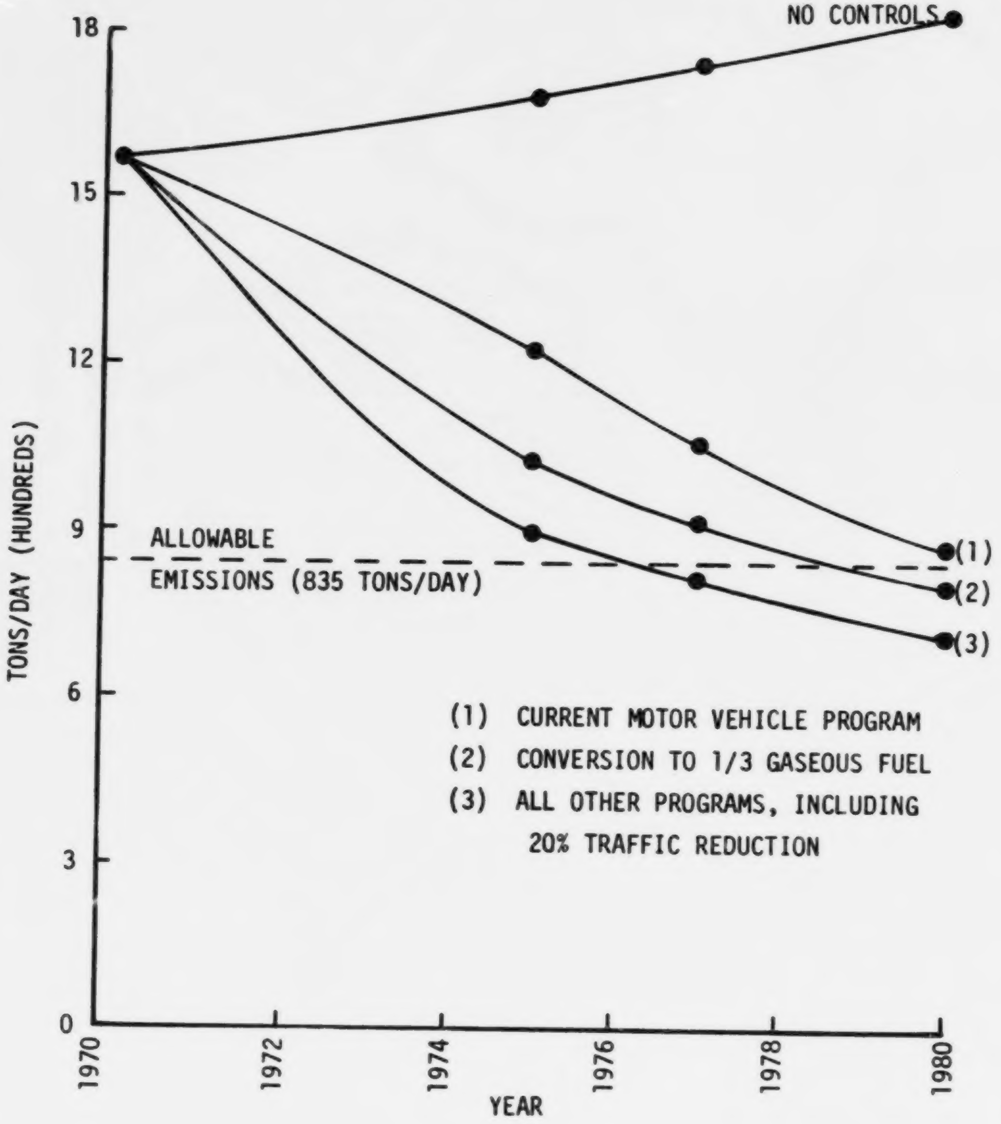

Figure 3.2. Proposed California Air Resources Board Strategy Nitrogen Oxides Emission Controls (1970 - 1980).

Source: California Air Resources Board, February 1972.

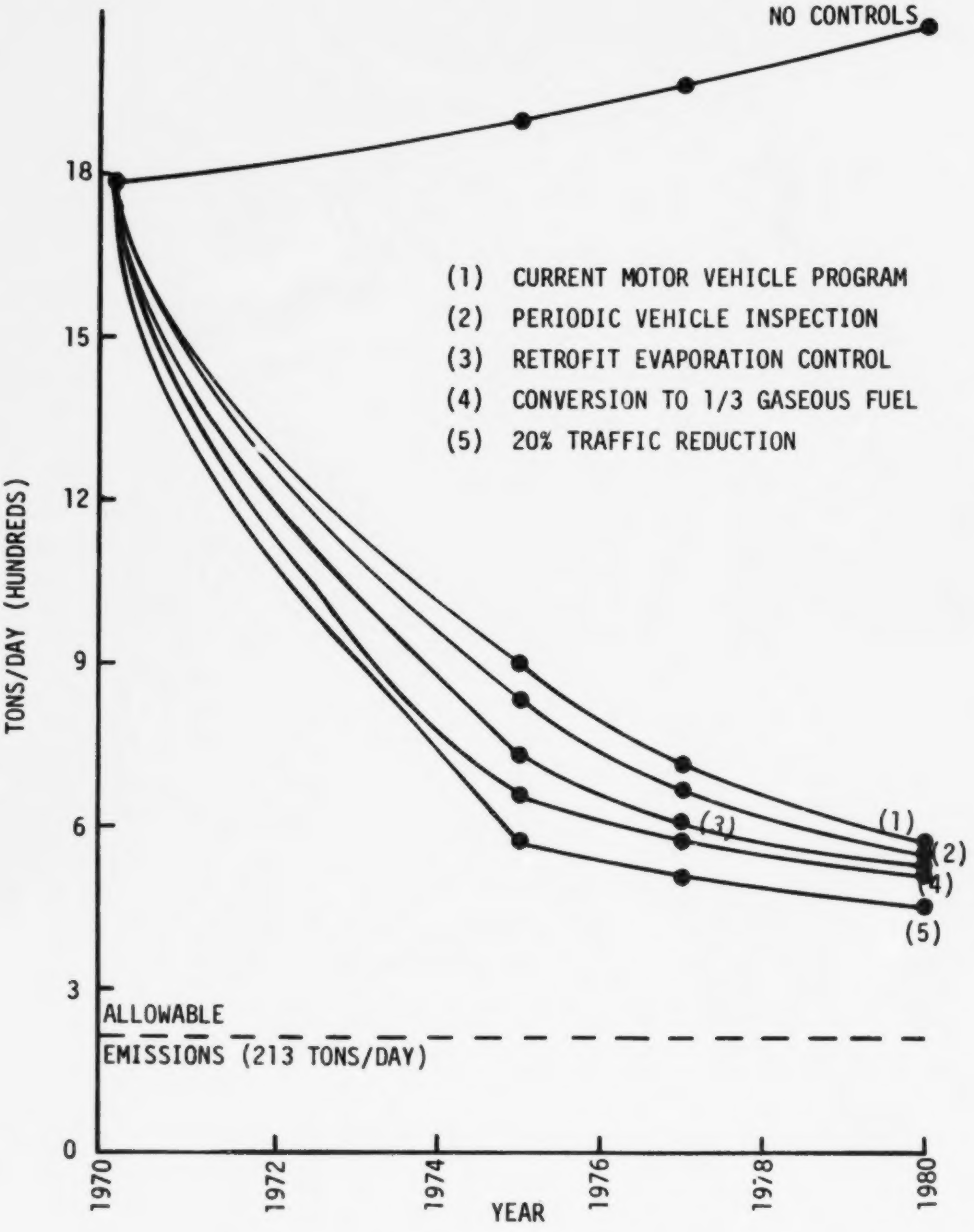

Figure 3.3. Proposed California Air Resources Board Strategy Photochemical Oxidant Emission Controls*

*(Based on Controlling Reactive Hydrocarbons).

Source: California Air Resources Board, February, 1972.

Table 3.1 CALIFORNIA AIR RESOURCES BOARD IMPLEMENTATION PLAN REDUCTIONS FROM PERIODIC VEHICLE INSPECTION (Tons/Day)

	CO	NO_X	RHC
1975	-1600(-27%)	+45(+5%)	-75(-11%)
1977	-1120(-26%)	+60(+9%)	-45(-7%)

Assumptions:

1) Projected growth (CARB)

2) Current motor vehicle programs

Table 3.2 DRAFT OF PROPOSED CHANGES TO EPA TITLE 40 (40 CFR-PART 51) OCTOBER, 1972-REDUCTIONS FROM INSPECTION/MAINTENANCE

HC-12%

CO-10%

NO_X-0%

Program Requirements:

- Mandatory inspection/maintenance using a loaded emissions test.
- Establishment of failure criteria consistent with claimed reductions.
- Insurance that failed vehicles receive necessary maintenance.
- Enforcement program to discourage and insure against intentional readjustments or modifications after inspection.

The major discrepancy in emission reductions likely to result from an inspection and maintenance program is the CO reduction taken by the ARB. Modification of this reduction claim alone results in the State being over the CO air quality standard in 1975 and requiring a two year extension to meet the standard by 1977.

The reductions claimed by the State for a massive conversion to gaseous fuels are also high. Initial estimates seem high both with regard to the percentage emission reductions possible and the number of vehicles which could conceivably be converted. Section 4.3 of the report discusses the issue of gaseous fuel conversion in the South Coast Air Basin.

On November 21, 1972 at the Air Resources Board's monthly meeting, several revisions were made to reductions resulting from various options. The principal changes (see Tables 3.3 and 3.4) confirmed the results of our analysis. Revision of both claims for inspection and maintenance and gaseous fuel conversion programs reflected a significantly lower impact than originally calculated.

Table 3.3 ESTIMATED EFFECT ON TOTAL EMISSIONS FROM VEHICLE EMISSION CONTROL OPTIONS IN THE SOUTH COAST AIR BASIN - 1975

(Tons/Day)

Sources	Carbon Monoxide	Oxidant[1]	Oxides of Nitrogen
Stationary Sources with Controls	65	140	357
Mobile Sources before Control	11930	1690	1290
Projected Totals	11995	1830	1650
Projected Reduction from Mobile Sources	8625 (9510)[2]	1305 (1325)	660 (780)
Remaining Controllable Emissions	3370 (2485)	525 (505)	990 (870)
Allowable Emissions	2481	213	835
%Reduction from 1970 Emissions	70 (80)	70 (70)	40 (50)

[1] Based on emissions of highly reactive organic gases.

[2] ( ) Estimates shown in Implementation Plan.

Source: Presented at the Air Resources Board Monthly Meeting, San Francisco, California, November 21, 1972.

Table 3.4 ESTIMATED EMISSION REDUCTIONS DUE TO VEHICLE EMISSION CONTROL OPTIONS FOR THE SOUTH COAST AIR BASIN - 1975

(Tons/Day)

Option	Carbon Monoxide	Oxidant[1]	Oxides of Nitrogen
Current Program[2]	6030 (6030)[3]	1000 (1000)	450 (450)
1955-1965 Catalytic Converter Retrofit	160	10	2
1966-1970 Catalytic Converter Retrofit	660	50	8
Periodic Vehicle Inspection	210 (1600)	25 (70)	-
Evaporative Control Retrofit[4]		160 (160)	-
Gaseous Fuel Conversion	1015 (1330)	40 (75)	70 (200)
20% Traffic Reduction	550 (550)	85 (85)	130 (130)
Totals	8625 (9510)	1370 (1390)	660 (780)

[1] Based on control of emissions of highly reactive organic gases.

[2] Includes the reductions resulting from installation of ARB approved devices for 1955-65 and 1966-70 vehicles.

[3] ( ) Estimates shown in Implementation Plan.

[4] Includes control on gasoline marketing operations and retrofitting 1966-69 vehicles with evaporative control.

Source: Presented at the Air Resources Board Monthly Meeting, San Francisco, California, November 21, 1972.

3.2 The Caltech Environmental Quality Laboratory Plan

Since its inception in 1970, the Environmental Quality Laboratory (EQL) at the California Institute of Technology has been actively engaged in working on environmental problems. Towards the end of 1972, they published a plan for attacking the photochemical smog problem in Los Angeles (46). The EQL plan is a comprehensive set of strategies developed by a team of engineers, lawyers, social scientists and students.

Certain aspects of the EQL plan are strategies proposed by the ARB in its Implementation Plan; other control measures have been proposed elsewhere. However, despite the massive impact the EQL strategies would have on the Basin's residents, the plan does not meet the federal air quality standards. It was a deliberate decision of the EQL study team to "consider only those air pollution control strategies that comply with the spirit (if not the letter) of the Clean Air Act of 1970". Their assessment of the requirements of the Clean Air Act of 1970 and the State's proposed Implementation Plan is summarized as follows (46):

> "The California strategy, on one hand, and the federal requirements, on the other, seem to represent two extremes. One was so slow that the time when economic growth and population growth would overtake control measures could be readily predicted. This would happen sometime in the middle of the 1980's. The other was so rapid that only a sudden and wrenching curtailment of transportation and economic activity could produce the required results. In the latter case, the cure might be worse than the disease."

The EQL approach to this problem is the adaption of "management standards" in which the number of days on which air quality standards are exceeded is significantly reduced (but never reaches the one day per year violation allowed for by the Clean Air Act). If the "EQL Strategy #1" is implemented, the team estimated the number of days the oxidant standard would be exceeded would drop from 241 days in 1970 to 50 days in 1975 and hopefully, to 25 days per year by 1977.

The key elements of the "EQL Strategy #1", as it relates to motor vehicles are summarized below in Table 3.5. When some recommended stationary source control measures are added, the estimated cost of the first phase of the "EQL Strategy #1" is approximately one billion dollars through the end of 1975.

A summary of the impacts of the "EQL Strategy #1" on improving air quality is given in Figures 3.4 and 3.5. Several points of interest are brought out by the EQL analysis:

- presently proposed control strategies do improve the situation through at least 1980.
- the "EQL Strategy #1" would result in a more rapid improvement of air quality, although falling short of the national photochemical oxidant standard.
- the EQL analysis suggests the goal of no more than one violation per year for oxidants cannot be met in the South Coast Air Basin.

Part of the "EQL Strategy #1" is a series of social and economic incentives to discourage individual auto usage such as: 1) an emissions tax based on the amount of pollutants discharged into the atmosphere,

Table 3.5 EQL STRATEGY #1 FOR MOTOR VEHICLES

	Measure	Estimated Cost thru 1975 (millions)	Cost Borne By
1.	Mandatory conversion of commercial fleet vehicles to burn a gaseous fuel by December 31, 1973	\$400	Loss of Federal and State tax revenues
2.	a) Mandatory installation on 1960-65 vehicles of a control device to reduce HC emissions by 60% and NO_x emissions by ~35%	\$ 70	Consumer
	b) Mandatory installation on 1966-70 vehicles of a control device that reduces NO_x emissions substantially	\$225	Consumer
3.	Mandatory installation of an evaporative control device on 1966-69 vehicles to reduce fuel tank evaporative emissions by 90%	\$200	State and Consumer
4.	Mandatory vehicle emissions inspection system for all cars	"Emissions tax" revenues	Consumer
5.	Social and economic incentives to discourage individual automobile use		

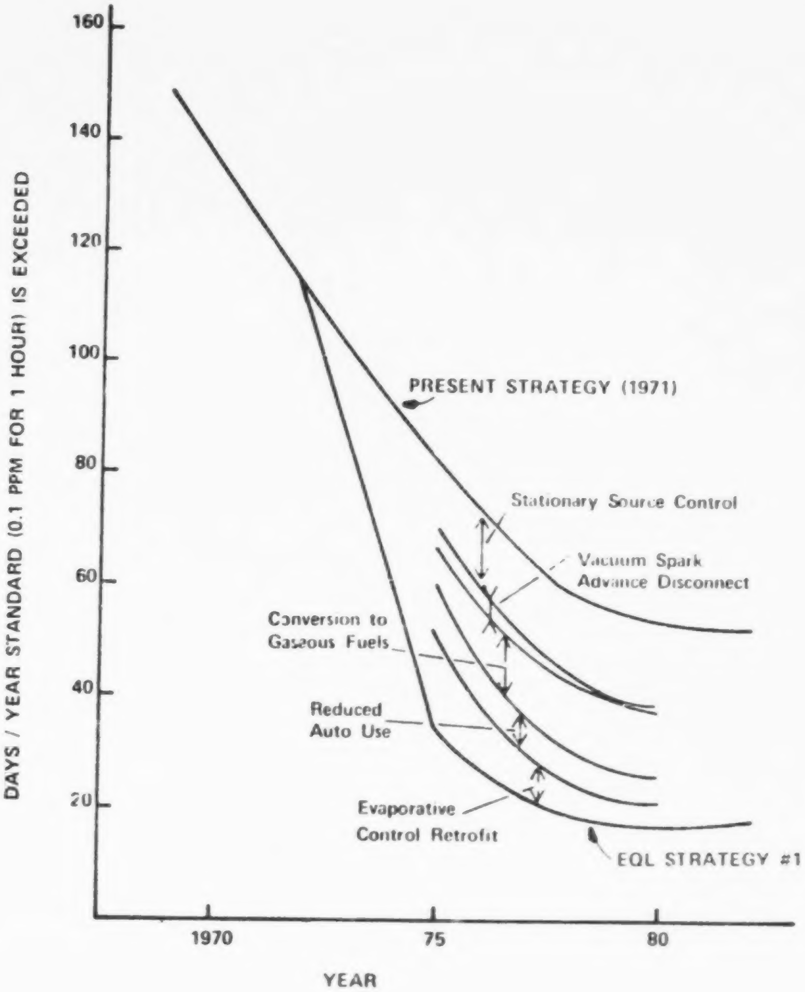

Figure 3.4. Breakdown of Improvement in Oxidant Air Quality for Downtown Los Angeles.

Source: Lees, L., et. al., Smog: A Report to the People, Environmental Quality Laboratory, California Institute of Technology, 1972, p. 152.

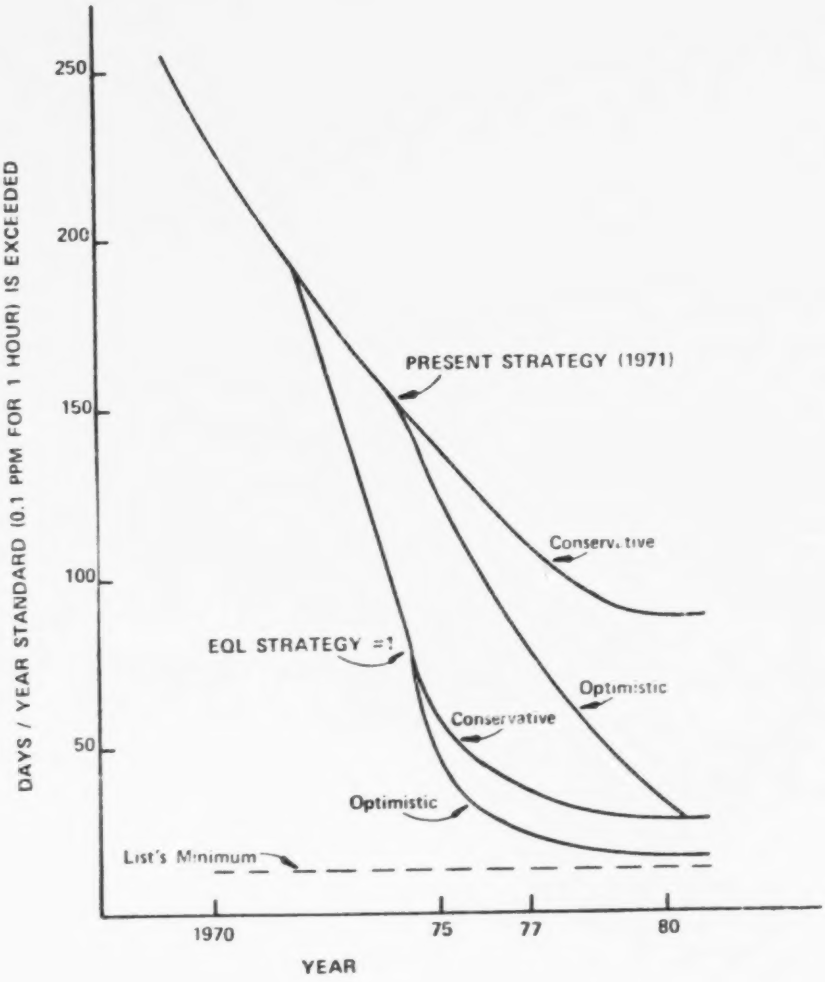

Figure 3.5. Various Projections for Improvement in Oxidant Air Quality for the South Coast Air Basin.

Source: Lees, L., et. al., Smog: A Report to the People, Environmental Quality Laboratory, California Institute of Technology, 1972, p. 160.

2) exclusive freeway lanes for buses and carpools, 3) extended ramp metering to control access onto the freeways, 4) free or subsidized parking for carpoolers, 5) a subsidy for improving public transit services and as a last resort, 6) either increased gasoline taxes or a ceiling placed on the volume of gasoline consumed within the Los Angeles Basin. The EQL study team estimated these socio-economic measures would result in a 20% reduction in vehicular emissions after their other measures were instituted (Note: the CARB also proposed a 20% reduction in auto usage through incentive type measures).

To date it has been extremely difficult to estimate quantitatively the probable impact of these incentive type measures. Various people have labelled such endeavors as "social engineering", an area in which comparatively little is known.

Using a demand elasticity model developed for the transportation planning agencies in the Los Angeles region, we have attempted to perform some "social engineering" analyses. These results, presented in sections 7.2 thru 7.10 are a first order approximation of the probable impact of a host of incentive type measures. The results will show that due to a variety of situations which presently exist in the Basin, the probable impact of a host of incentive type control strategies would be less than a 10% VMT reduction and probably not much more than a 5-8% reduction.

3.3 Emission Inventory Revision

During the course of the study, it became necessary for the EPA to develop a strategy to meet the air quality standards by January 15, 1973. As a result of this activity, personnel from both the EPA and the ARB re-evaluated portions of the California emission inventory. Special emphasis was placed on updating and revising the mobile source emission inventory in the South Coast Air Basin. A summary of portions of the revised motor vehicle emission contributions for the Los Angeles region is presented in Appendix N.

Again, a variety of control strategies were examined and a "plan" developed. Table 3.6 presents a preliminary set of controls with the accompanying reductions associated with each. The key element to the plan is a massive VMT reduction accomplished through gasoline rationing. Due to time constraints it was impossible to carry out a detailed evaluation of either the modified emission inventory or the impact of all the strategies proposed. In fact, some of the proposed strategies were clearly beyond the scope of the present analysis, e.g., additional stationary source controls. The revised emission inventory has been accepted as given for this report. Based on the revised inventory, the maximum allowable emissions for reactive hydrocarbons was set at approximately 161 tons/day.

3.4 Control Strategy Options

The previous sections have discussed various control strategies which have been evaluated by various groups and agencies. During the course of this study, a wide array of control strategy options were likewise evaluated, including specific measures which have not previously been analyzed. Table 3.7 summarized the control measures evaluated.

The control measures basically fall into two classes: motor vehicle oriented strategies and traffic (or VMT) oriented strategies. The traffic oriented strategies can be divided further into traffic flow strategies and VMT reduction strategies.

Table 3.6 COMPILATION OF CONTROL STRATEGY AFFECTS ON JUNE 30, 1977

	Tons/Day
Allowable Emissions	+ 161
Stationary source emissions considering no additional controls since 1970	+ 215
Stationary Control Strategy Reductions	
a. Gas rationing	- 62
b. Gasoline marketing	- 11
c. Dry cleaning vapor control	- 6
d. Degreaser substitution	- 25
e. Rule 66 strengthening (50%)	- 45
Stationary Emissions Remaining	+ 66
Mobile source emissions from aircraft, on-highway light and heavy duty vehicles, and motorcycles	+ 477
Mobile Control Strategy Reductions	
a. Aircraft emission reductions	- 11
b. VSAD and PCV State retrofit	- 19
c. Inspection and maintenance	- 39
d. Vehicle evaporative control retrofit	- 26
e. Gaseous fuel conversion	- 12
f. Oxidizing catalyst retrofit	- 84
g. VMT reduction by gasoline rationing	- 191
Mobile Emissions Remaining	+ 95
Total Mobile and Stationary Emissions Remaining	+ 161

Note: The reductions claimed from these strategies are a function of the order in which they were applied; therefore, the reductions claimed from one strategy should not be directly compared with those from others.

Source: Environmental Protection Agency, Region IX, December, 1972

Table 3.7 CONTROL STRATEGY OPTIONS

Motor Vehicle Oriented	Traffic (or VMT) Oriented	
	Traffic Flow Strategies	VMT Reduction Strategies
● Inspection/Maintenance	● Traffic Improvement Programs	● Improved Public Transit
● Retrofit Devices	● Ramp Metering	● Incentives to Discourage Auto Use
● Gaseous Fuel Conversion	● 55 M.P.H. Speed Limit	● Auto Free Zones
● Evaporative Loss Control	● Staggered Work Hours	● Increased Parking Fees
		● Four Day Work Week
		● Exclusive Bus and Carpool Lanes
		● Limited Registration
		● Gasoline Rationing

Chapter 4 discusses the motor vehicle oriented programs. Appendices L and M contain an expanded discussion of evaporative loss controls and gaseous fuel conversion programs, respectively.

Chapters 6-8 present a fairly detailed analysis of the traffic oriented strategies. Again, several appendices have been included as relevant support materials (Appendices E, F, G, H, I).

3.5 Interim Control Measures

The air quality data clearly show the photochemical oxidant problem to be seasonal in nature. Oxidants occur more frequently and severely during the summer months when the temperatures are highest and the photochemical activity greatest.

To date, all calculations which have analyzed the air pollution problem have assumed implicitly that pollutant emissions are discharged at a relatively uniform rate (e.g., 500 tons per day of CO). The difference in emission levels which occur on weekends is again assumed to be minor. These assumptions may, in fact, be very misleading.

Figure 3.6 presents data on the monthly volumes of gasoline sold within California. Besides the steady growth rate (~4 percent/year), a significant variation occurs in the amount of gasoline consumed monthly. There is approximately a 25 percent variation between the maximum to minimum monthly gasoline consumption figures within any given year.

To test the significance of this fact, several correlations were run. The percentage of annual gasoline consumed per month was correlated with the percentage of days within a month which exceeded various California air quality standards. Figures 3.7 and 3.8 present the results for the

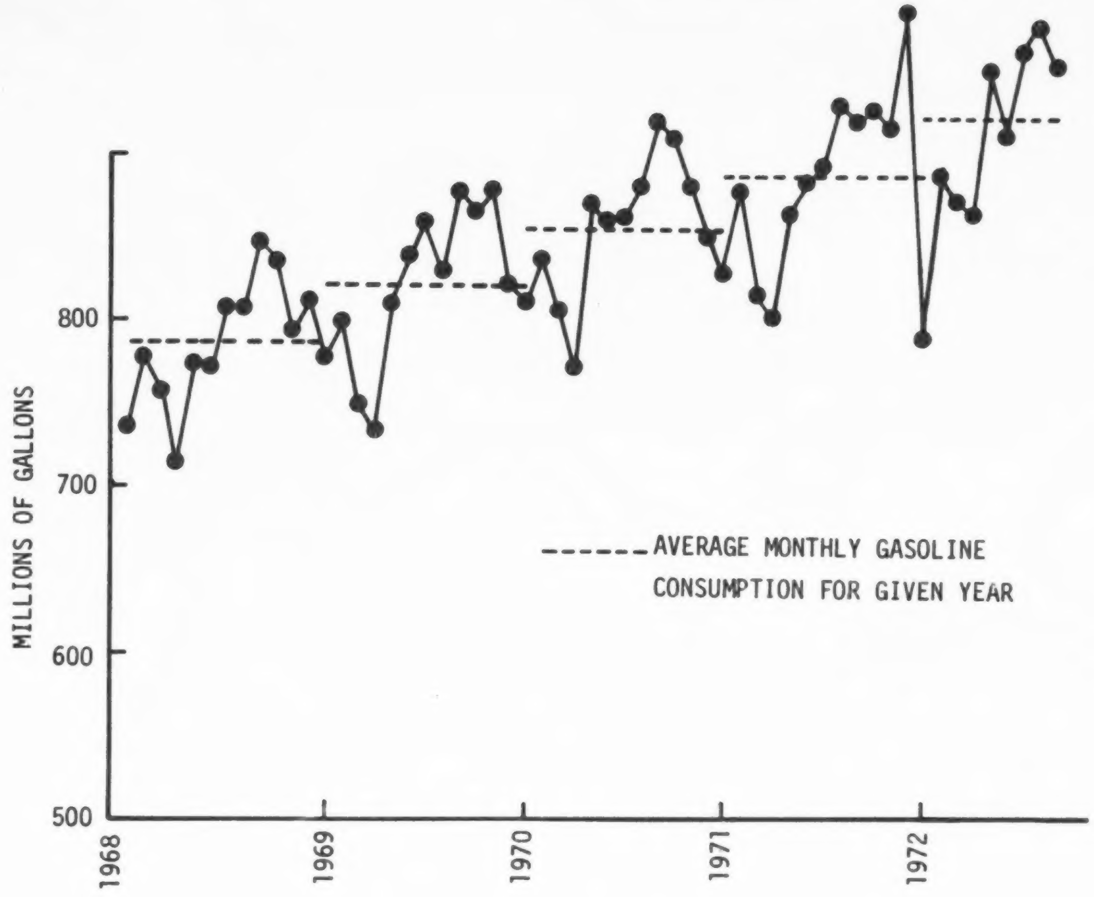

Figure 3.6. State of California - Monthly Gasoline Consumption (1968 - 1972).

Source: Division of Accounting, Controller of the State of California. The Data are Based on Revenues Collected from the 7¢ Per Gallon Gas Tax.

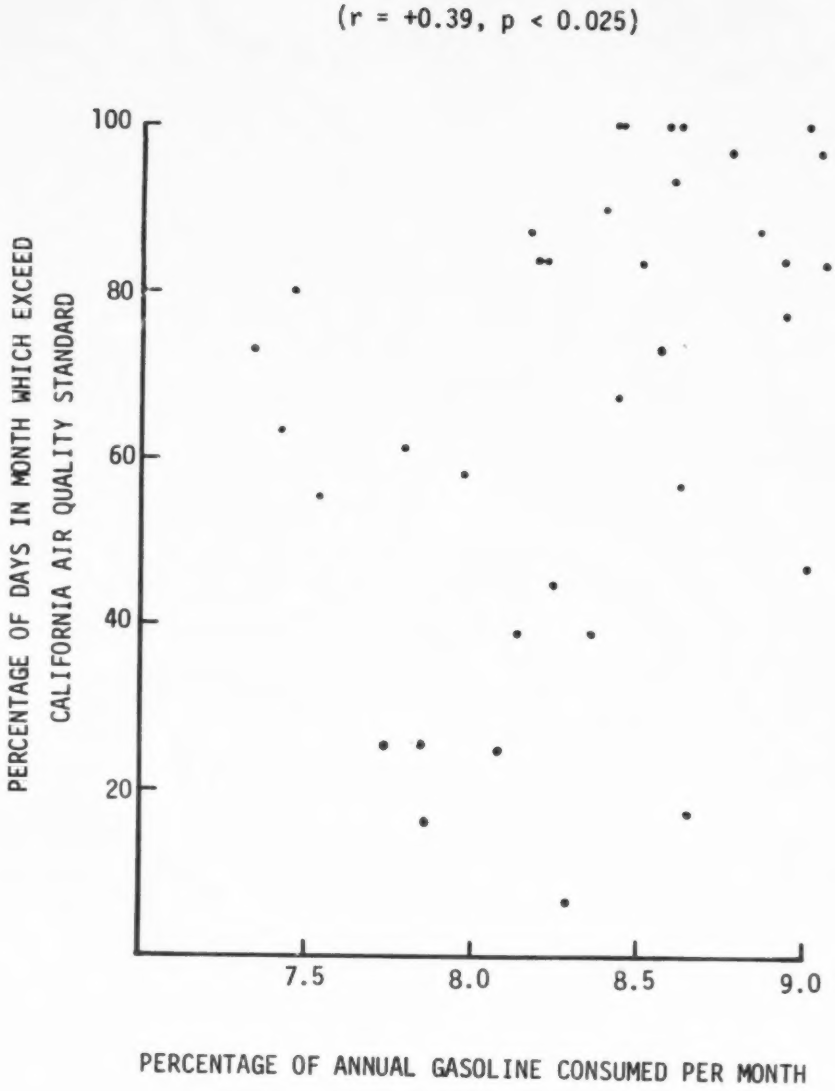

Figure 3.7. Correlation of Monthly Gasoline Consumption with Oxidant Air Quality Violations.

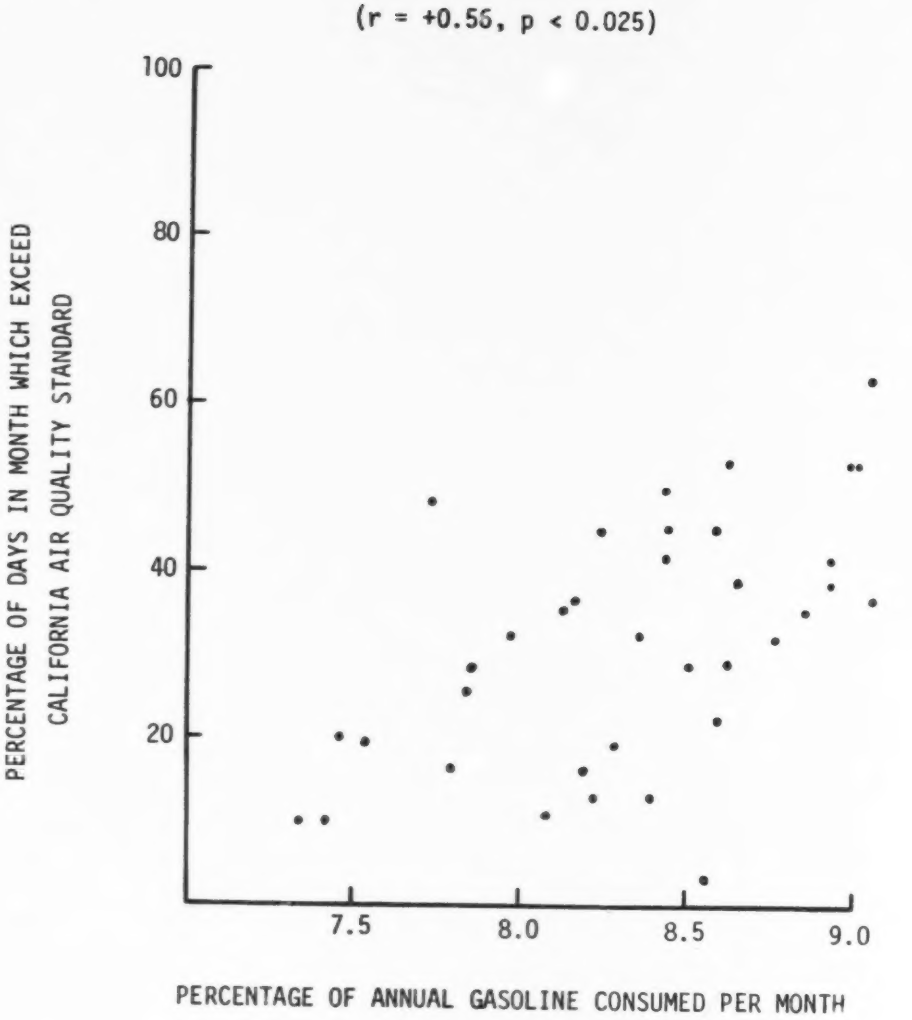

Figure 3.8. Correlation of Monthly Gasoline Consumption With Nitrogen Dioxide Air Quality Violations.

three most recent years air quality standards violations by month were available (1968-1970). While the correlation coefficients were not extremely high, they did prove to be significant. In all likelihood, meteorological parameters such as those discussed previously (Section 2.2.2) are the main determinants of air quality violations. However, it does appear that increased gasoline consumption during the summer months is a significant variable in causing air quality standards to be violated. A more detailed statistical analysis, which incorporated the various meteorological parameters, would be necessary to evaluate more definitely what the various contributions were to the total number of violations (e.g., use of stepwise multiple regression techniques).

In view of the above analysis, evaluation of control strategies which could be instituted on an interim basis deserve consideration. Interim controls have been defined in this report as those measures which could be applied for a specific seasonal problem. It should not be construed to mean measures such as those used during "episode" conditions, e.g., shutting down power plants and/or closing off all the freeways to traffic. Controls used for trying to avoid a one-day-per-year violation of 0.08 ppm oxidant are completely different from those which try to avoid two-to-three-day "stagnation" periods of 0.50 ppm peak oxidant. In the latter, one has a reasonable lead time to implement and enforce an emergency episode plan. These options are not available for trying to avoid a 0.08 ppm oxidant standard (one-hour average).

Certain strategies can easily be applied on an interim basis whereas other measures must be considered fixed once implemented. Due to the procedures used for compiling emission inventories, it is all but impossible to know accurately what the monthly or weekly fluctuations are in pollutant emissions discharged. Consequently, one is unable to quantitatively assess the probable impact on air quality improvements from interim controls which attempt to explicitly consider such variations.

Table 3.8 gives a number of examples of possible interim controls which might be implemented. Several of these measures have been evaluated in the report. The definite seasonal nature of the ozone problem would suggest a more detailed analysis of these types of control strategies is warranted.

Table 3.8 EVALUATION OF SOME INTERIM CONTROL STRATEGIES[a]

Control Strategy	Relative Adaptability for Interim Control	Relative Effectiveness as an Interim Control	Example
Gaseous Fueled Vehicles	Medium	Medium	Dual fuel systems which burn gaseous fuels during the summer, regular gasoline during the winter
Retrofit Devices	Very low	- -	- - -
55 M.P.H. Speed Limit	High	Low	Speed limit changes in summer and/or daytime
Limited Registration	Very low	- -	- - -
Pricing Schemes	Low-Medium	- -	- - -
Gasoline Rationing	High	High	Rationing from May-October

[a] Assuming no difficulty in implementing the control measure.

4.0 MOTOR VEHICLE ORIENTED STRATEGIES

Motor vehicle oriented controls fall into several categories, each designed ultimately at reducing the average vehicular emissions discharged. The specific controls evaluated were listed in Table 3.7. The following briefly summarizes the intent of each control strategy.

- Inspection/Maintenance – designed to reduce emission through a program of inspection followed by the required tuning, repairs, etc., necessary to allow each car to operate at its minimum emission potential.
- Retrofit Devices – generally aimed at cleaning up the emissions after they are generated, usually through more complete combustion.
- Gaseous Fuel Conversion – designed to reduce emissions through the use of "cleaner" burning fuels, e.g., compressed natural gas or liquified petroleum gas.
- Evaporative Loss Controls – aimed at controlling the loss of hydrocarbons from evaporation, generally by recirculation, trapping mechanisms, or condensation processes.

4.1 Inspection/Maintenance Measures

Inspection/maintenance approaches reduce emissions from in-use motor vehicles by insuring that the auto population is maintained in a manner sufficient to keep emission at a minimum. This approach is generally implemented by requiring regular mandatory maintenance, or maintenance based on the results of periodic inspection results; usually this involves either an engine diagnostic or exhaust emission test. It has been demonstrated that significant emission reduction can be achieved by the proper servicing of the vehicle population. In addition, inspection becomes a necessary enforcement tool if new or retrofit emission control devices are required.

The State of California has required emission control devices to be installed on automobiles for a number of years. To ensure compliance, the State initiated and continues to operate several inspection programs including the Certificate of Compliance and roadside inspection. A new owner of a used car must obtain a Certificate of Compliance from a Class A station (a private garage or service station licensed by the State) before having his car registered. In order for the certificate to be issued, the car is tested for proper functioning of its emission control system. Regulations specify that engine operations be verified with diagnostic test equipment and the idle speed, air/fuel ratio, and ignition timing reset to manufacturer's specifications if necessary.

The California Highway Patrol administers the roadside inpection program, through which about 15 percent of the cars registered in California are inspected each year. In addition to a safety inspection, vehicles have their emissions checked at idle; those failing the emission test are required to have adjustments made at a Class A station.

Results from the above inspections and other test programs indicated that it was not unusual to find cars which discharge contaminants several times the average emission and that most of these cars could be restored to a reasonable level of emission by a simple tune-up. In light of the potential emission reductions obtainable by identifying autos that require servicing, the increasing complexity of new car emission controls, and the growing probabilities that additional retrofit devices would be required for in-use vehicles, considerable interest developed for a mandatory inspection program. As a result, the 1970 California Legislature directed the Air Resources Board to undertake a study to determine the reductions in automotive emissions that could be achieved from vehicle emission inspection programs. They were also asked to determine the cost of carrying out such programs on a permanent basis.

4.1.1 The Northrop Study(55, 56)

The ARB responded to this legislative directive by issuing a contract to The Northrop Corporation, in association with Olson Laboratories, to determine the feasibility of implementing a mandatory periodic inspection program. The effectiveness and cost of five alternate inspection test regimes were analyzed to determine which (if any) would be optimum for a mandatory program. These regimes were certificate of compliance, idle test, key mode test, diagnostic test, and an annual adjustment and maintenance procedure (AAMP).

The Certificate of Compliance procedure investigated was similar to the program already in operation and described above. It includes a sequence of operations which involves inspection and servicing of crankcase devices and exhaust emission control systems. The procedures for inspection and adjustment are specified in a handbook issued by the Department of Consumer Affairs, and the actual work is performed by garages licensed by the Department of Consumer Affairs.

The Idle Inspection is performed by operating the vehicle to be tested at idle and analyzing a sample of the exhaust to determine pollutant emission levels. If a vehicle does not pass the established emission limits, it is then required to receive corrective maintenance. This method is effective for isolating high emitters and is well suited for inspection by private garages.

The Diagnostic Inspection studied is a sophisticated test concept involving the utilization of a skilled diagnostician, a chassis dynamometer and engine analysis equipment. The vehicle is operated on a chassis dynamometer at various engine load modes. During each of the operating modes, the exhaust gas is analyzed for pollutant emissions. The vehicles exceeding the established limits are diagnosed by the diagnostician and then repaired. This method is very effective in pinpointing defective components; however, it is time consuming and requires high levels of training.

The Annual Adjustment and Maintenance Procedure (AAMP) is a mandatory maintenance program in which the vehicle is repaired and adjusted to prescribed specifications without a prior emission test; adjustments are made according to a specified procedure. This procedure requires annual maintenance regardless of need and is generally effective in reducing emissions.

The Key Mode Inspection tests the vehicle operation on a simple chassis dynamometer at specified vehicle speed and load modes which expose engine faults. The operating modes that most reliably expose these faults are labeled "key" modes. The modes which have been identified and used are high cruise, low cruise, and idle. A sample of the exhaust gas is collected and analyzed for pollutant emissions. Limits are established for each mode. If the limits are exceeded, the vehicle requires corrective maintenance. By referring to a diagram termed a "truth chart", the most probable engine malfunctions are noted as an aid to the mechanic who then does the repair work.

The Northrop study concluded that mandatory periodic vehicle inspection is feasible and highly desirable in terms of emission reductions, program costs, vehicle owner costs, and public opinion. The study found that to be most cost effective, inspections should be performed by the State with repairs performed by private enterprise. Table 4.1 compares costs for implementing the four proposed inspection methods Statewide. Table 4.2 compares the average emission changes that were experienced by a test fleet comprised of over 1,000 passenger vehicles. The vehicles chosen were statistically representative of the California vehicle population.

Table 4.1 COMPARISON OF COSTS FOR FOUR PROPOSED INSPECTION METHODS

(1972 State-Owned and Operated Facilities)

Cost Element	Key Mode	Idle	Diagnostic	Certificate of Compliance
1. Capital Investment Costs	$19,830,000	$12,084,000	$88,776,000	$30,263,000
2. Annual Operating Costs*	10,476,000	9,576,000	30,688,000	23,110,000
3. Vehicle Owner Out of Pocket Costs** (per vehicle per year)				
Inspection Fee	$ 1.05	$ 0.96	$ 3.07	$ 2.31
Maintenance Costs	28.24	37.02	47.48	8.31

*The cost is defrayed by inspection fee.

**Inspection and maintenance, in most cases, would obviate the need for the normal annual tune-up and may produce fuel savings.

Source: State of California, The Resources Agency, Air Resources Board, "A Report to the Legislature on Vehicle Emission Inspection," July 1, 1971, p. 10.

Table 4.2 EMISSION PROFILE CHANGES FOR TOTAL FLEET

NOTE: Total fleet includes vehicles that were serviced combined with those that did not require service.

Test Regime	HC (%)	CO (%)	NO_x (%)
Certificate of Compliance			
Controlled Vehicles	-21.8	-5.6	4.68
Uncontrolled Vehicles	-9.6	-5.53	3.72
Idle			
Controlled Vehicles	-17.0	-26.0	4.45
Uncontrolled Vehicles	-29.0	-20.8	5.65
Key-Mode			
Controlled Vehicles	-27.8	-33.4	3.92
Uncontrolled Vehicles	-30.0	-36.6	23.4
Diagnostic			
Controlled Vehicles	-16.4	-23.0	4.53
Uncontrolled Vehicles	-36.6	-24.9	10.7
AAMP			
Controlled Vehicles	-23.6	-12.5	1.30
Uncontrolled Vehicles	-33.5	-19.9	-1.45

It is important to note that measured NO_x emissions in this program may not be typical of future years. NO_x control devices are now being installed on newer vehicles and will be required on all future vehicles. None of the tested vehicles for this program had such controls. It is reasonable to expect that an inspection and maintenance program will ultimately be effective in keeping these controls operating properly and thereby achieve reductions in in NO_x emissions.

Source: Northrop Corporation with Olson Laboratories, Inc., Mandatory Vehicle Emission Inspection and Maintenance, Part B - Final Report, Volume V, Part 1, Summary, December 1971, p. S-4.

Of the inspection regimes studied, the key mode test conducted in State-owned facilities appeared to be the most cost effective. The idle test regime was nearly as cost effective as the key mode during the same time frame. According to the study, the certificate of compliance program conducted by the service industry produced the least benefits in terms of emission reduction. The major conclusions were that an inspection program would significantly reduce CO and HC emissions, but might increase NO_x emissions somewhat on pre-1970 vehicles; the instrumentation equipment required was available. It was also anticipated that there would be wide public acceptance of a vehicle inspection program.

4.1.2 Technical Advisory Committee Report (94)

During the same time frame as the Northrop study, the Technical Advisory Committee (TAC) to the California Air Resources Board also examined the cost and effectiveness of various vehicle inspection schemes (as well as retrofit systems), and concluded that some mandatory annual inspection and maintenance system would be needed if exhaust controls were to be required on used cars and also because of the sophisticated new car controls expected on the 1974 and later models. The TAC recommended that a method for annual inspection be developed and that present Class A testing stations be converted into upgraded stations.

4.1.3 California Air Resources Board Report (95)

On July 1, 1971, the California Air Resources Board reported back to the Legislature on their findings and recommendations for Vehicle Emission Inspection. The following are direct excerpts from that report.

SUMMARY

1. The study by Northrop and evaluation by the Board's Technical Advisory Committee both indicate that inspection and mandatory maintenance is technically feasible and that it would achieve some reductions of hydrocarbons and carbon monoxide emissions from motor vehicles, but it would increase oxides of nitrogen. The decision to undertake an inspection program, however, should not be based on technical feasibility alone. The expected benefits of the program must be balanced against the adverse effects of oxides of nitrogen increase, costs, inconvenience to the motorists, the requirement of trained and skilled personnel.

2. On a long-term basis, regular inspection and maintenance is needed. All or most of the cars will be equipped with systems that involve engine modifications, advanced control systems or combinations of these approaches. Inspection and periodic maintenance are required to ensure their continual effectiveness.

3. Any inspection method, if it is to be suitable, must be adaptable to future requirements, because technology of emission control is changing. What is appropriate today may be obsolete a few years later.

4. It would not be prudent to embark at this time on an inspection program which requires permanently committed installations and large capital investments. Such a program should be amenable to easy modifications.

5. To be effective, a mandatory inspection and maintenance program must be manned by qualified personnel and the programs must be closely supervised.

RECOMMENDATIONS

1. A statewide inspection program that requires the acquisition of State operated installations, dynamometers and testing equipment, not be established at this time.

2. A pilot inspection program using highly qualified stations be undertaken.

3. The pilot program should include determinations of:

    a. The applicability of annual inspection involving mandatory diagnosis, adjustment and repair to minimize motor vehicle emissions.

    b. The extent of upgrading service personnel needed and the means by which upgrading can be accomplished.

    c. The advantages and the problems of this inspection and maintenance system under actual operating conditions.

4.1.4 Legislative Action (61)

In the Analysis of the Budget Bill of the State of California for the Fiscal Year July 1, 1972 to June 30, 1973, the California Legislative Analyst, A. Alan Post, recommended that the Legislature add $21,929,000 to the Air Resources Board budget to institute a program in the Los Angeles Air Basin for mandatory inspection of used cars and vacuum spark advance disconnect. These figures were based on the Northrop study Key Mode Recommendation and consider the following: (a) approximately 288 inspection lanes are required at an average cost for capital equipment and building of facilities of $48,820 per lane for a total cost of $14,349,000 , (b) approximately 650 inspectors are required to operate and manage the 35 inspection stations at an annual operating cost of $26,320 per lane for a total cost of $7,580,000. This budget element was "blue pencilled" out of the final budget.

At least three separate bills were introduced into the California Legislature during the 1972 session which would have provided for vehicle inspections. Two were introduced in the Assembly and one in the Senate. All remained unacted upon at the close of the Legislature and are assumed to be dead (see Appendix J, Section 2).

4.1.5. Governor's Task Force on Vehicle Inspection (72)

On February 29, 1972, Governor Reagan established a task force composed of representatives of the Air Resources Board, the Department of Motor Vehicles, the Highway Patrol, the Department of Consumer Affairs, and the Department of Finance to confirm the need for inspection and/or maintenance for emission control and to recommend specific legislation for completing the program. In October of 1972, the task force reported back to the Governor with a recommended program that primarily differs from the present program, only in the requirement that all future commercial repair work relating to emissions be done in accordance to State-prescribed regulations (with misdemeanor charges for those mechanics not complying with procedures). The program called for expansion of random roadside idle emission testing and an expanded consumer affairs program. The annual costs for such a program are shown in Table 4.3.

Table 4.3 ANNUAL COST OF GOVERNOR'S TASK FORCE RECOMMENDED PROGRAM
CALIFORNIA STATEWIDE

	Total Cost -$-	Present Cost -$-	Additional Cost -$-	Source of Funds
Cost of Required Repairs	72,600,000	61,500,000	11,100,000	Vehicle Owner
Owner's Time Cost	8,000,000	5,100,000	2,900,000	Vehicle Owner
C.H.P. Inspection Cost	5,600,000	3,800,000	1,800,000	Motor Vehicle Fund
Consumer Affairs Supervision	3,100,000	600,000	2,500,000	Station License Fees
Program Evaluation	600,000	-	600,000	Motor Vehicle Fund
TOTALS	89,900,000	71,000,000	18,900,000	

The task force considered two stages of program expansion. Both would replace the requirement that a certificate of compliance be issued only on a change of ownership. The first option is an annual idle emission test at licensed stations with mandatory adjustment and maintenance of vehicles failing the test; the second option is the key-mode test as recommended by the Northrop study in State-owned, State-operated stations. The task force recommended the decision on the implementation of either expansion option be differed pending further study of uncertainties in future system requirements and the apparent declining benefits in the mass of emissions controlled with time.

4.1.6 Discussion

The Governor's task force identified the key operation in an inspection/ maintenance system as properly performed maintenance. However, the requirement that all commercial repair work relating to emissions be done according to State prescribed procedures appears to be difficult to enforce. The mechanic will often come under pressure from his customer to tune for performance instead of emissions. As a result, regulated tune-ups would become unenforceable unless violators were vigorously prosecuted. Under present conditions, this does not appear very likely.

A more workable solution would be to base the requirement for, and success of, maintenance on a direct emission test rather than a "certificate of compliance". This action would remove the mechanic from the difficult position of trying to meet contradictory requirements - - those of his customer and those of the State. A test result is more impartial and appears to provide a consistent criteria for the mechanics to follow.

Every group that has studied the problem has recognized the requirement for periodic inspection/maintenance. Also recognized, is the severity of the air pollution problem in the Los Angeles Basin. Therefore, it is recommended that a mandatory inspection/maintenance program be implemented. As a minimum, "Option II" studied by the Governor's task force should be implemented; this program is essentially the stage 1 expansion program cited by the task force. Such a program would require a mandatory annual idle emissions test with those failing the test being repaired by a State-prescribed maintenance schedule. For maximum air quality benefits, the second stage expansion program of the Governor's task force report should be implemented:

> "Annual key mode testing at State-owned and State-operated inspection stations with mandatory adjustment and maintenance of failed vehicles at licensed private garages."

Implementation of either program would result in a net reduction of approximately 10-12% of the emitted hydrocarbons, with the second program (key mode) resulting in a larger reduction.

4.2 Retrofit Device Measures

A retrofit measure is defined as the application of any device or system that may be added to a motor vehicle and/or any modification or adjustment beyond that of regular maintenance which could be made to reduce vehicular emissions. There are three primary emission sources in motor vehicles which can be potentially controlled by various retrofit measures. For vehicles without emission controls, crankcase venting typically contributes about 20 percent of the total hydrocarbon emissions from the vehicle. Another 20 percent of the total hydrocarbon emissions are evaporative losses from the carburetor and the fuel tank system. Exhaust emissions account for all the carbon monoxide and oxides of nitrogen emissions from uncontrolled vehicles.

Crankcase emission devices were required on new cars in the State of California beginning in 1963. Exhaust emissions were required on new cars beginning in 1966 and evaporative controls were required in the 1971 model year. Several retrofit programs have been carried out or are in progress in California. Because photochemical smog is the biggest problem in the Los Angeles area, the effectiveness of reducing hydrocarbons and, to a lesser extent, oxides of nitrogen is the main requirement for retrofit systems. Crankcase devices are required on 1955-65 automobiles, upon change of ownership or initial registration in California. As of September, 1972, oxides of nitrogen and hydrocarbon exhaust emission devices are required on 1955-65 automobiles in the Los Angeles Air Basin. By April, 1973, oxides of nitrogen exhaust control devices, in this case, vacuum spark advance disconnect (VSAD), will be required on 1966-70 model year vehicles in the Los Angeles area. Enforcement will begin during the 1975 vehicle registration cycle.

There are no retrofit devices available at present to control evaporative hydrocarbon emissions from the fuel systems. However, the State has recently initiated a research and development program for just such a system. If a practical device is developed, it should be seriously considered for implementation as 20 percent of the hydrocarbon emissions from pre-1971 automobiles could be eliminated with its application.

The ARB's evaluation program of the evaporative loss controls should be completed by late 1973; if warranted, it will be followed by a certification program. To implement a mandatory installation program, additional legislation will be required. It is recommended that the entire evaluation, testing, and certification program be accelerated. The benefits of this control measure are significantly diminished by a one-two year delay because of the normal replacement of older vehicles with newer, controlled vehicles.

Many exhaust emission control retrofit devices have been evaluated and the results are summarized in an EPA report titled, "Control Strategies for In-use Vehicles." In addition, the Technical Advisory Committee to the California Air Resources Board performed an in depth study (94) on the emission control of used cars, covering the available options, effectiveness, cost and feasibility of these measures. The reader should refer to these sources for a detailed description of the operation, performance and effectiveness of most (if not all) retrofit devices presently available. The more successful retrofit options are sited in a draft revision to the implementation regulations and are listed in Table 4.4 along with their average pollution reduction and typical installed costs. Table 4.5 presents a summary of the results of the Technical Advisory Committee study.

The Air Resources Board has established testing facilities and capable personnel to objectively evaluate emission control devices. The Board also cooperates with various private companies in the development testing of automobiles fitted with the latest emission control measures.

As an example, 50 new G.M. cars are presently under test. These autos have devices (including oxidizing catalytic converters) designed to meet the 1975 Federal new car standards.

Based on the findings summarized in Tables 4.4 and 4.5, and considering the major retrofit programs already underway, the only "cost effective" exhaust retrofit device that has not yet been scheduled for implementation in the Los Angeles area is the oxidizing catalytic converter. The catalytic converter is highly effective in reducing hydrocarbon and carbon monoxide emissions and can be added to autos that have already had the VSAD retrofit as easily as to "unmodified" autos. The actual converter is a device installed in the engine exhaust system between the exhaust manifold and the muffler. On older cars, it would require detuning to allow the car to run on lead free gasoline. This is because the catalyst can be "poisoned" by leaded fuel although recent prototype tests have shown the catalyst to be somewhat tolerant of lead-containing fuel if it is not used more than 10 percent of the time (50)

Several potential problems exist for any major retrofit program of oxidizing catalytic converters. Tests have shown one problem in these converters is the emissions of ammonia and aldehydes in the final exhaust. Aromatic aldehydes can lead to the formation of peroxybenzoyl nitrate (PBZN), the aromatic analog of the more commonly known PAN (peroxyacetyl nitrate). Oxidizing catalytic converters generally require the use of lead free gasoline. To date, the major refineries have maintained their octane levels by substituting aromatic compounds (e.g., toluene) for the lead removed. PBZN, is a potent lachrymator and has caused eye irritation

Table 4.4 RETROFIT CONTROL MEASURES

Retrofit Option	Installed Cost	Average Reduction per Vehicle HC	CO	NO_x
Pre-controlled Vehicles				
Lean Idle Air/Fuel Ratio Adjustment and Vacuum Spark Advance Disconnect	$ 20	25%	9%	23%
Oxidizing Catalytic Converter and Vacuum Spark Advance Disconnect	195	68%	63%	48%
Air Bleed to Intake Manifold	60	21%	58%	0%
Exhaust Gas Recirculation and Vacuum Spark Advance Disconnect	110	12%	31%	48%
Controlled Vehicles				
Oxidizing Catalytic Converter	$175	50%	50%	0%
Exhaust Gas Recirculation	90	0%	0%	40%

Source: Environmental Protection Agency

Table 4.5 SUMMARY OF COST AND EFFECTIVENESS CALCULATIONS

CONTROL OPTION	Cost Averaged over All Cars: $/Car/Year	Cost Effectiveness: $ per Car for 5 yrs per Equiv. Reactive Ton/Day	Average 5-Year Effectiveness: Equiv. Reactive Ton/Day	Average Reduction of Total Emissions from Used Cars in Next 5 Years %	Possibility of Implementation in 2 Years (10 - high)
1. Inspection and Rejection of Upper 25% of Cars (all cars)	10.75	1.92	28	5.2	8
1a Key-Mode-Rejection of Upper 50% (Northrup)	5.29	0.85	31	5.7	-
1b Same as 1a with inspection cost at $5.00	11.21	1.81	31	5.7	-
2. Emission Testing at Roadside (one in ten cars each year)	1.83	3.26	2.8	0.5	10
3. Periodic Idle Adjustment (all cars)	5.00	1.19	21	3.9	10
4. Certification of Exhaust Controls at Time of Resale (all cars)	1.25	1.57	4.1	0.8	10
5. Annual Diagnosis, Repair and Adjustment to MPC (all cars)	10.20	0.73	70	13	8
6. Used Car Retrofit Kits (pre-1966 cars)	8.00	0.80	50	9.2	9
7. Vacuum Spark Advance Disconnect (all cars)	13.00	0.38	172	32	9
8. Vacuum Spark Advance Disconnect + Option 5 (all cars)	23.20	0.48	242	44	8
9. Detuning for Unleaded Fuels & Oxidation Catalyst + Option 5 (all cars)	40.20	1.07	168	34	6
10. Option 9 + Option 7 (all cars)	53.20	0.74	360	66	6
11. Option 10 + Exhaust Gas Recirculation (all cars)	63.20	0.70	454	83	5
12. Thermal Afterburner (pre-1966 cars)	14.10	1.60	44	9.1	5
13. Option 12 (pre-1966 cars) + Option 7 (all cars)	27.10	0.63	216	39.7	5
14. Detuning for Unleaded Fuels & Oxidation-Reduction Catalyst + Option 5 (all cars)	55.80	0.62	454	83	1
15. Conversion to Natural Gas* + Option 5 (all cars)	8.20	0.10	405	74	0
16. Conversion to LPG* + Option 5 (all cars)	69.60	0.75	465	85	0
17. Conversion to Methanol* + Option 5 (all cars)	245.60	2.50	490	90	0

* It is assumed that the present price and tax privileges will continue through the 5-year period.

Source: California Air Resources Board, Technical Advisory Committee, Emission Control of Used Cars; Available Options: Their Effectiveness, Cost and Feasibility, June 1971, p. 10.

at levels as low as 5 ppb. It is conceivable that a major retrofit program involving oxidizing catalytic converters would substitute one problem for another. Oxidant levels could go down with no improvement in the eye irritation situation.

Currently, there are at least two suppliers of this type converter; but it is doubtful sufficient devices and adequate installation training could be provided in the time frame required for this measure to be fully implemented by the 1977 clean air target date. It is recognized that every additional emission reduction possible is required if the Clean Air Act requirements are to be met; however, much more testing is required before a major catalytic converter retrofit program can be unequivocally recommended.

4.3 Gaseous Fuel Conversion

Studies have shown that the fuel, supplies, distribution systems, and conversion equipment could become available for the conversion of several hundred thousand fleet vehicles to gaseous fuels in the South Coast Air Basin (32, 46). For those vehicles converted, the use of gaseous fuels results in a significant reduction of emissions. Also, the combustion products from gaseous fueled vehicles have been shown to be less reactive than emissions from gasoline powered engines -- an important consideration in areas such as Los Angeles where photochemical smog is the dominant problem.

To achieve the stipulated and desired emission reductions possible from gaseous fuel conversions, proper maintenance and tuning for minimum emissions is a necessity. Gaseous fueled vehicles frequently emit more pollutants than conventional gasoline powered vehicles due to improper tuning. Furthermore, gaseous fueled vehicles can operate without a noticable effect on drivability even though they are quite out of tune. It is important, therefore, that any large scale conversion program be accompanied by a mandatory inspection and maintenance program. This could readily be accomplished through the recommended program discussed in Section 4.1.

Conversion of fleet vehicles to gaseous fuels is a very cost effective program since the capital investment can generally be recovered in two-to-five years; this usually depends on the number of cars in the fleet and the mileages driven. To date, the majority of conversions have been justified on the basis of overall cost savings; the air pollution benefits have been an added bonus. In general, maintenance costs and requirements are less than for conventional gasoline powered vehicles. Not all converted fleets have been able to register an overall cost savings from their conversion efforts; consequently, in any massive conversion strategy, one can expect a fraction of the fleets to experience financial losses. Overall, however, the number of fleets saving money should out number the fleets losing money with a net savings from all fleets converted.

Gaseous fueled vehicles used in strict compliance with applicable standards and maintained by qualified repairmen are as safe as present gasoline operated motor vehicles. Fleet operators have not encountered any difficulty in insuring their gaseous fueled vehicles at normal rates and driver acceptance to gaseous fueled vehicles is varied, but favorable overall.

A key element in this control strategy is the timing. Presently, the only vehicles which can obtain the gas-tax exemptions are those vehicles which have been converted to California approved systems and meet 1974 California emission standards. Thus, any conversions which are to have an impact should be pre-1975 vintage motor vehicles. This implies a gaseous fuel conversion program should be initiated as soon as possible and completed no later than the end of 1974.

Since the typical lifetime of fleet vehicles is less than average cars, a reasonable target group of cars would be the 1970-1974 fleet vehicles. The conversion of pre-1970 vehicles does result in greater percentage-wise reductions than post-1970 vehicles, but the necessity to drive a fleet vehicle two-to-five years effectively precludes the likelihood of converting these vehicles.

Detailed fleet vehicles statistics for California and the South Coast region have recently become available from the Department of Motor Vehicles. Table 4.6 shows private fleet vehicle statistics for California and the South Coast area. In addition to private fleets, there were approximately 194,000 public fleet vehicles (e.g., governmental and post office vehicles) in California in 1970. Assuming half of these vehicles are located in the South Coast Air Basin suggests some 530,000 fleet vehicles reside in the region presently.

Figure 4.1 illustrates the emission reductions resulting from a mandatory fleet conversion of 1970-1974 vehicles. Tables 4.7 through 4.11 present the various emissions from vehicles using the different fuel systems. The ARB has estimated the average mileage of fleet vehicles

Table 4.6 CALIFORNIA PRIVATE FLEET VEHICLE STATISTICS

DISTRIBUTION BY COUNTY

COUNTY	NUMBER OF FLEET VEHICLES[1]
Los Angeles	276,966
Orange	29,329
Riverside	6,234
San Bernardino	7,114
Ventura	4,854
Out of State	200,289
CALIFORNIA TOTAL	828,169
ESTIMATED SOUTH COAST BASIN PRIVATE FLEET POPULATION [2]	428,000

DISTRIBUTION BY MODEL YEAR

YEAR	NUMBER OF FLEET VEHICLES	% FLEET VEHICLES
1972	168,726	20.37
1971	131,569	15.89
1970	118,028	14.25
1969	101,915	12.31
1968	62,499	7.55
1967	42,632	5.15
1966	40,676	4.91
Pre - 1966	162,124	19.58

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[1] Ten or more vehicles registered under one name.

[2] Five counties listed plus a proportionate fraction of the out of state fleet vehicles.

SOURCE: Department of Motor Vehicles, State of California, October, 1972.

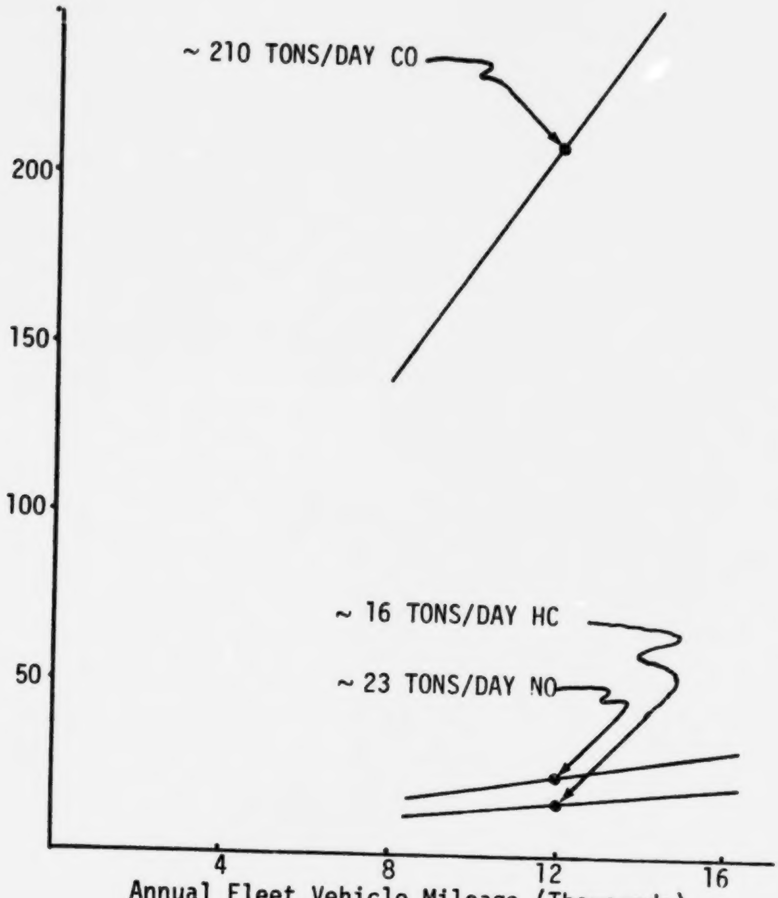

Figure 4.1 Emission Reductions from Gaseous Fuel Conversion (South Coast Air Basin - 1977)

Assumptions:

1) Fleet population of ~580,000 vehicles or approximately a 10% growth of 1972 fleet populsion (~530,000).
2) Same model year distribution as State's in October 1972.
3) Conversion of 1970-1974 vehicles only.
4) Emission factors provided by the CARB.
5) 75% VMT using natural gas
   25% VMT using LPG
   } Proposed by Caltech EQL

Table 4.7 GASOLINE POWERED VEHICLE EMISSIONS
(gm/mi)

Vehicle		1974			1975			1977			1980	
Model	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
1976	-	-	-	0.14	1.4	0.3	.15	1.5	.34	0.16	1.6	.34
1975	0.3	2.4	1.0	0.14	1.4	0.9	.16	1.6	1.0	0.17	1.7	1.1
1974	1.2	18.4	1.1	1.2	18.4	1.1	1.25	18.8	1.2	1.3	19.2	1.2
1973	1.3	21.2	2.6	1.3	21.2	2.6	1.35	21.4	2.7	1.4	21.6	2.8
1972	1.5	24.0	3.0	1.5	24.0	3.0	1.55	24.0	3.0	1.6	24.0	3.1
1971	2.3	25.0	4.0	2.3	25.0	4.0	2.3	25.0	4.0	2.3	25.0	4.1
1970	2.8	26.0	4.1	2.8	26.0	4.1	2.8	28.5	4.2	2.8	31.0	4.2
1969	3.6	36.0	4.3	3.6	36.0	4.3						
1968	3.9	37.0	3.8	3.9	37.0	3.8						
1967	4.4	40.0	3.6	4.4	40.0	3.6						
1966	5.0	41.0	3.8	5.0	41.0	3.8						

Source: California Air Resources Board, April 1972

Table 4.8 EMISSIONS FROM MOTOR VEHICLES USING NG
(gm/mi)

Vehicle Model	HC	CO	NO_x
1976	.14	1.4	.3
1975	.14	1.4	.6
1974	.35	4.0	.6
1973	.35	4.0	.6
1972	.35	4.0	.6
1971	.50	4.0	.9
1970	.50	4.0	1.3
1969 and older	.80	6.2	1.3

Source: California Air Resources Board, April 1972

Table 4.9 EMISSIONS FROM MOTOR VEHICLES USING LPG
(gm/mi)

Vehicle Model	HC	CO	NO_x
1976	.14	1.4	.3
1975	.14	1.4	.6
1974	.35	5.0	.6
1973	.35	5.0	.6
1972	.35	5.0	.6
1971	.50	5.0	.8
1970	.50	5.0	.8
1969 and older	.80	7.3	.8

Source: California Air Resources Board, April 1972

Table 4.10 DIFFERENCE IN EMISSION BETWEEN GASOLINE POWERED VEHICLES AND NATURAL GAS POWERED VEHICLES (gm/mi)

Vehicle Model	1974			1975			1977			1980		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
1976	--	--	--	.00	.0	.0	.00	.0	.00	.00	.0	.00
1975	.00	.0	.3	.00	.0	.3	.00	.0	.4	.00	.0	.5
1974	.85	14.4	.5	.85	14.4	.5	.90	14.8	.6	.95	15.2	.6
1973	.95	17.2	2.0	.95	17.2	2.0	1.00	17.4	2.1	1.05	17.6	2.2
1972	1.15	20.0	2.2	1.15	20.0	2.4	1.20	21.0	2.4	1.25	20.0	2.5
1971	1.8	21.0	3.1	1.8	21.0	3.2	1.8	21.0	3.1	1.8	22.0	3.2
1970	2.3	22.0	2.8	2.3	22.0	3.3	2.3	24.5	2.9	2.3	27.0	2.9
1969	2.8	29.8	3.0	2.8	30.8	3.0						
1968	3.1	31.8	2.5	3.1	31.8	2.5						
1967	3.6	34.8	2.3	3.6	34.8	2.3						
1966 and older	4.2	35.8	2.5	4.2	35.8	2.5						

Source: California Air Resources Board, April 1972

Table 4.11 DIFFERENCE IN EMISSIONS BETWEEN GASOLINE POWERED VEHICLES AND LPG POWERED VEHICLES (gm/mi)

Vehicle Model	1974			1975			1977			1980		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
1976	--	--	--	.00	.0	.0	.00	.0	.0	.0	.0	.0
1975	.00	.0	.4	.00	.0	.4	.00	.0	.5	.0	.0	.6
1974	.85	13.4	.5	.85	13.4	.5	.90	13.8	.6	.95	14.2	.6
1973	.95	16.2	2.0	.95	16.2	2.0	1.00	16.4	2.1	1.05	16.6	2.2
1972	1.15	19.0	2.2	1.15	19.0	2.4	1.20	20.0	2.4	1.25	19.0	2.5
1971	1.8	20.0	3.2	1.8	20.0	3.2	1.8	20.0	3.2	1.8	21.0	3.3
1970	2.3	21.0	3.3	2.3	21.0	3.3	2.3	23.5	3.4	2.3	26.0	3.4
1969	2.8	29.0	3.5	2.8	29.0	3.5						
1968	3.1	31.0	3.0	3.1	31.0	3.0						
1967	3.6	34.0	3.8	3.6	34.0	3.8						
1966 and older	4.2	35.0	3.0	4.2	35.0	3.0						

Note: The Air Resources Board had recently (December, 1972) revised some of the values presented in Tables 4.7 through 4.11. They should be consulted for the most recent data.

Source: California Air Resources Board, April 1972

through surveys to be approximately 12,400 miles per year. The conversion program would affect slightly less than 300,000 vehicles (or approximately 5 percent of the Basin's automobile population.)

In view of the overall cost effectiveness of this strategy, it is recommended that a mandatory conversion of fleet vehicles of model years 1970-1974 be implemented in the South Coast Air Basin as soon as possible, and completed no later than January 1975. Additional recommendations are:

- accelerate the vehicle replacement program as soon as vehicles meet the 1975-76 emission standards, rather than continuing the conversion program.
- insure for the continuation of a fuel tax exemption beyond 1975; this is necessary to maintain the cost effectiveness of the program.
- investigate approaches to circumvent the implementation obstacles.

The implementation obstacles to an effective gaseous fuels conversion program are:

1) the present lack of legal authority for the ARB to implement the program; Senate Bill 657 (see Appendix J - Section II), which would have called for a mandatory conversion of fleet vehicles to gaseous fuels in the South Coast Air Basin, died in Committee, November 16, 1972.
2) public opposition to such a program by certain large fleet operators, e.g., The Yellow Taxi Cab Association.
3) existing regulations dealing with the handling, storage, and transportation of gaseous fuels.
4) enforcement problems for the large number of out-of-state fleet vehicles which operate in the Basin or the many cars which will change their registration to a County outside of the Basin if such a program was started.

Appendix "M" delves into many of the critical aspects of gaseous fuel conversion; it also summarizes some of the history of attempts in California to get such a measure implemented.

4.4. Evaporative Losses from Service Station Fueling Operations

The handling and transfer operations associated with the sale of gasoline contribute a substantial portion of hydrocarbon emissions through evaporative losses. As exhaust emission control standards for motor vehicles become more stringent, the proportionate share of hydrocarbon emissions coming from evaporative losses will increase.

This section attempts to review hydrocarbon losses from what are normally the last two fuel handling operations -- the filling of underground storage tanks at the service station and the filling of automobile gasoline tanks from these storage tanks. The combined uncontrolled emissions from these two sources are projected to be approximately 132 tons per day in 1972 and 159 tons per day in 1977. These projections assume the limit on Reid vapor pressure from April through October as set forth by the CARB. Assuming no control methods are instituted, these two sources become a significant air pollution source by 1977.

A variety of control options are available for reducing the evaporative emissions cited. The analysis of costs and effectiveness for a series of available alternatives is presented in Appendix L. A summary of the results and recommendations are:

- Implementation of a control scheme which returns the displaced vapors from the motor vehicle fuel tank to the storage tank from which the gasoline is pumped.

This can be accomplished by ensuring a tight seal at the interface between the fill nozzle and the fuel tank fill pipe. The fill nozzle must be designed so that there is a space around the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the displaced vapors from the fuel tank into the underground storage tank from which the fuel is pumped. Depending on the availability of an effective fill nozzle, this control strategy would have an estimated annualized cost of $3 million per year for removal of approximately 71 tons/day of gasoline vapors in 1977. This amount of removal would take place during the April-October peak smog period. Somewhat less than 71 tons/day would be removed during the remaining months of the year. Completion of a changeover to a standardized automotive fill pipe would result in approximately a 90 tons/day reduction during the most severe smog periods by 1985.

- Encourage the imposition of a requirement for standardized automotive fill pipe. This changeover would eventually be required in any case if a national system of evaporative controls is required.

- Implementation of further controls on the Reid vapor pressure in the South Coast Air Basin is not recommended at this time.

Further research on the validity of the reactivity scales as they relate to real atmospheric phenomena is undoubtedly appropiate. Also, a better understanding is needed of the impact of gasoline modification on all emissions subsequent to the fuel change. This recommendation would not necessarily apply to other air basins. In fact, the joint LAAPCD, ARB, and Western Oil study on the subject specifically states regarding its results:

> "The results of the study must be used with caution .... these estimates are applicable only to Los Angeles County because the temperature data are not necessarily representative of other areas .... the degree of air pollution reduction attainable by this means in Los Angeles County will be different from that in any other community .... because application of certain rules and controls already in effect here have reduced emissions from stationary sources to a greater extent than in most other communities.... attempts to apply the results of the study to any other area or season could be hazardous and misleading and are strongly not advised." (12)

5.0 THE SOUTH COAST TRANSPORTATION AND TRAFFIC DATA BASE

The currently projected motor vehicle emissions control programs will be inadequate by themselves to bring about sufficient reductions to achieve the national ambient air quality standards by the 1975-77 target dates. Additional control strategies, especially in the area of transportation controls, are necessary for attainment of the desired goals within the above time frame. Of primary concern is reaching the photochemical oxidant standard, which implies more stringent controls on the reactive hydrocarbons emitted and to a lesser extent controls on nitrogen oxides.

Mobile vehicle emissions are a function of many variables, some of which are related to the driving patterns of the motorists and street and highways conditions. Emissions are affected by the number of starts and stops, idling time, trip length, average speed, and individual driving habits.

Strategies aimed at reducing photochemically reactive emissions from motor vehicles involve either limiting the amount of gasoline consumed (i.e., prevention at the source) or improving the emission characteristics of the vehicles involved (i.e., cure of the source). Limiting the volume of fuel consumed implies reduction of vehicle miles travelled (VMT) within the Basin whereas lowering the emissions implies altering the parameters which influence the emissions (idle time, speed, or starts and stops). A variety of alternatives is available for implementing either approach. This section presents an analysis of programs designed to reduce VMT or to modify the VMT in such a way as to lower the overall emissions.

The majority of the transportation data for Southern California were derived from the California Division of Highways' ongoing Los Angeles Regional Transportation Study (LARTS). The LARTS study area includes all of Los Angeles, Orange, and Ventura Counties and the western, most intensively developed portions of Riverside and San Bernardino Counties (15). As such the geographic boundaries do not coincide exactly with the State's definition of the South Coast Air Basin. However, due to problems associated with trying to aggregate many types of data covering different political and geographic regions, it is assumed in this analysis that the LARTS study area is equivalent to the South Coast Air Basin. An analysis of the population figures for the two study areas shows them to be very comparable. Figure 7.10 gives a map of the LARTS study area.

Table 5.1 lists estimates for daily vehicle miles of travel for the five counties within the LARTS study area.

Table 5.1 VMT PROJECTIONS FOR THE LARTS AREA (millions of miles/day)

Year	Freeway	Non-Freeway	Total VMT
1967	56.694	69.253	125.947
1977[a]	84.769	82.861	167.630
1980	93.192	86.943	180.135

[a] linear extrapolation of the 1967 to 1980 growth rate

SOURCE: Personal communication, Advanced Planning Department, District 7 Division of Highways, November, 1972.

Detailed total VMT figures disaggregated by counties were unavailable. However, travel during the peak hour periods were projected by county for the same time period covered in Table 5.1. From these projections, total VMT breakdown during peak periods for 1977 (Tables 5.2 and 5.3) were estimated.

Table 5.2 PEAK PERIOD VMT[a] FOR THE LARTS AREA (millions of miles/day)

Year	Freeway	Non-Freeway	Total
1967	13.826	17.681	31.507
1977[b]	30.981	29.537	60.518
1980	36.132	30.490	66.622

---

[a] obtained by a separate assignment of home to work type trips to the highway network.

[b] linear extrapolation of the 1967 to 1980 growth rate.

SOURCE: Personal communication, Advanced Planning Department, District 7, Division of Highways, November 1972.

Table 5.3 PEAK PERIOD VMT BY COUNTY-LARTS AREA-1977

County	Percentage of Peak Hour VMT
Ventura	4
Los Angeles	68
Orange	7
Riverside[a]	5
San Bernardino[a]	16

---

[a] those portions within the LARTS study area.

SOURCE: Advanced Planning Department, District 7, Division of Highways

The 1967 and 1980 estimates were generated by the California Division of Highways via the LARTS traffic projection model, which was calibrated from 1967 origin-destination data. The 1980 estimates assumed the Division of Highway's best estimate as to which highways will be completed by 1980. Of the assumed new freeways, sections of Routes 90, 91, 105, 118 and 210, Route 105, the Century Freeway is the least likely to become reality by

1977. Consequently, 1,370,000 freeway vehicle miles were subtracted and 1,003,000 non-freeway vehicle miles were added to the system under the assumption that the Century Freeway would carry an average daily traffic of 80,000 cars and that 25 per cent of its vehicle miles would be generated by the presence of the freeway.

The total vehicle miles travelled within the South Coast Air Basin are the result of many trips of varying lengths and purposes. The LARTS 1967 origin-destination study defined, for example, 5 trip-purpose classifications. Certain types of trips are inherently more susceptible to controls than others; hence, an understanding of the fraction of travel attributable to each category of trip type is necessary. Table 5.4 presents data on trips for various purposes in the Los Angeles area.

Additional control strategies which are frequently considered relate to specific geographical areas, such as the central business district; others relate to the temporal distribution of traffic, e.g. staggered work hours. In order to assess these measures, it is necessary to know how VMT are distributed as a function of time and space.

The low density development characteristic of the Los Angeles region, has resulted in a relatively uniform distribution of miles travelled throughout the urbanized areas. This has contributed directly to the regional nature of the air pollution problem. Figures 5.1 and 5.2 graphically illustrate the relatively even, spread out nature of miles travelled in the Basin. The area illustrated is only a portion of the LARTS study area, but accounts for a large fraction of the total VMT. Table 5.5 presents the temporal distribution of the miles travelled shown in Figures 5.1 and 5.2.

Table 5.4 AVERAGE TRAVEL DATE (ONE WAY) ON TRIPS FOR VARIOUS PURPOSES

Trip Type	Trip Length (miles)	Speed (mph)	Travel Time (minutes)	Freeway (miles)	Percentage of Total Vehicle Miles[a]
Home to Work	10.5	26.3	23.0	3.8	32.4
Work to Other[c]	7.6	30.7	16.0	3.8	13.4
Home to Shop	3.0	22.1	8.2	0	4.3
Home to Other[b]	6.8	----	----	---	24.4
Other to Other[b,c]	6.8	----	----	---	25.5

---

[a] derived from LARTS 1967 O-D Study - Trip Purpose Frequency

[b] derived from LARTS 1967 O-D Study (these trips are too varied in nature to accurately predict speed, time, and freeway mileage).

[c] fleet vehicle travel is accounted for these two categories.

SOURCE: Adapted from A Survey of Average Driving Patterns in the Los Angeles Urban Area, D. H. Kearin and R. L. Lamoureux, Systems Development Corporation, TM-(L)-4119/000/01, February 28, 1969.

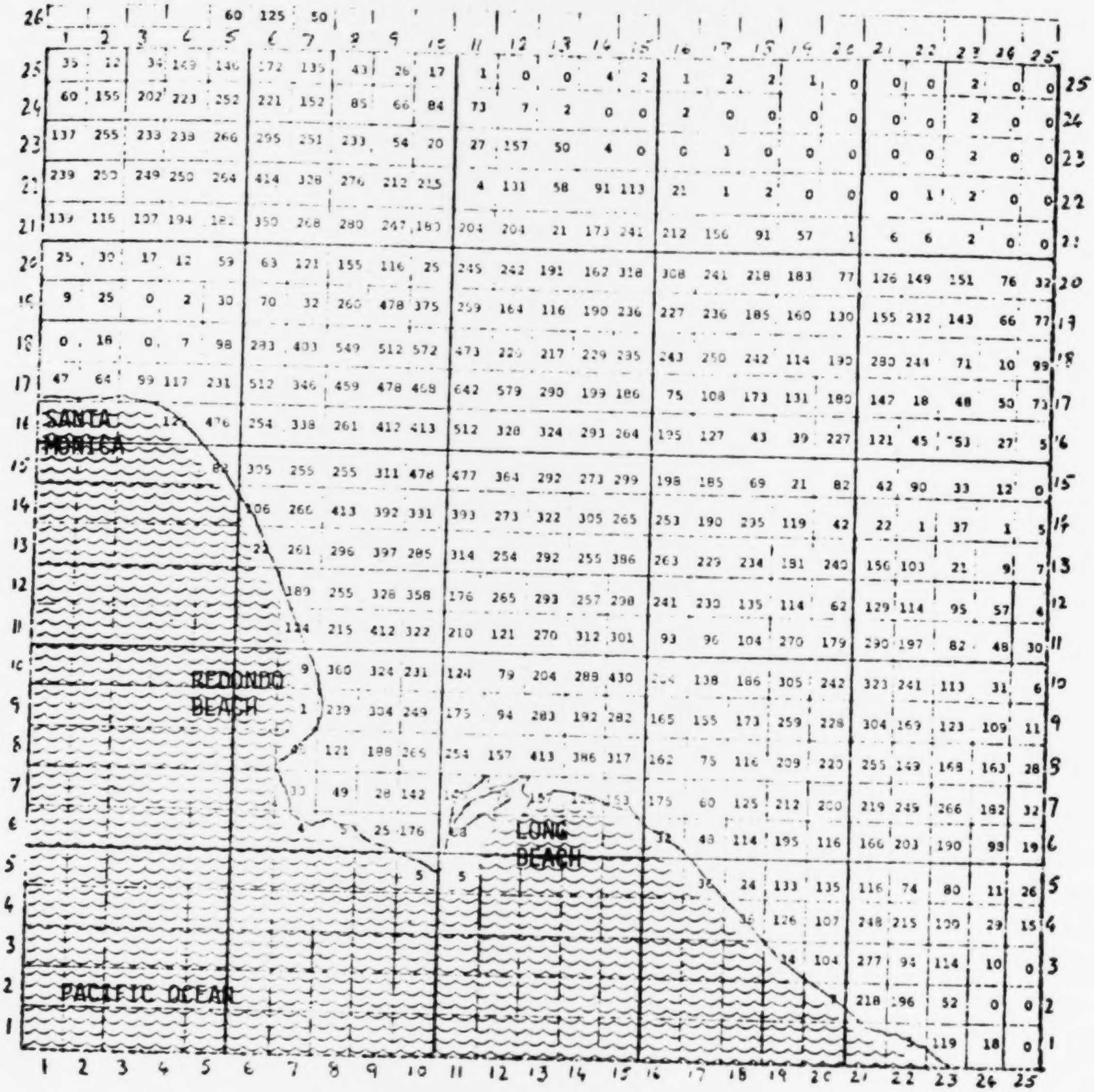
SANTA MONICA
REDONDO BEACH
LONG BEACH
PACIFIC OCEAN

Figure 5.1 Spatial Distribution of Non-Freeway Traffic (thousands of miles/day)

SOURCE: Roberts, P., P. M. Roth, and C. L. Nelson, "Contaminant Emissions in the Los Angeles Basin -- Their Sources, Rates and Distribution," Appendix A of Development of a Simulation Model for Estimating Ground Level Concentrations of Photochemical Pollutants, Systems Applications, Inc., Report 71 SAI-6, March, 1971 p. A-10.

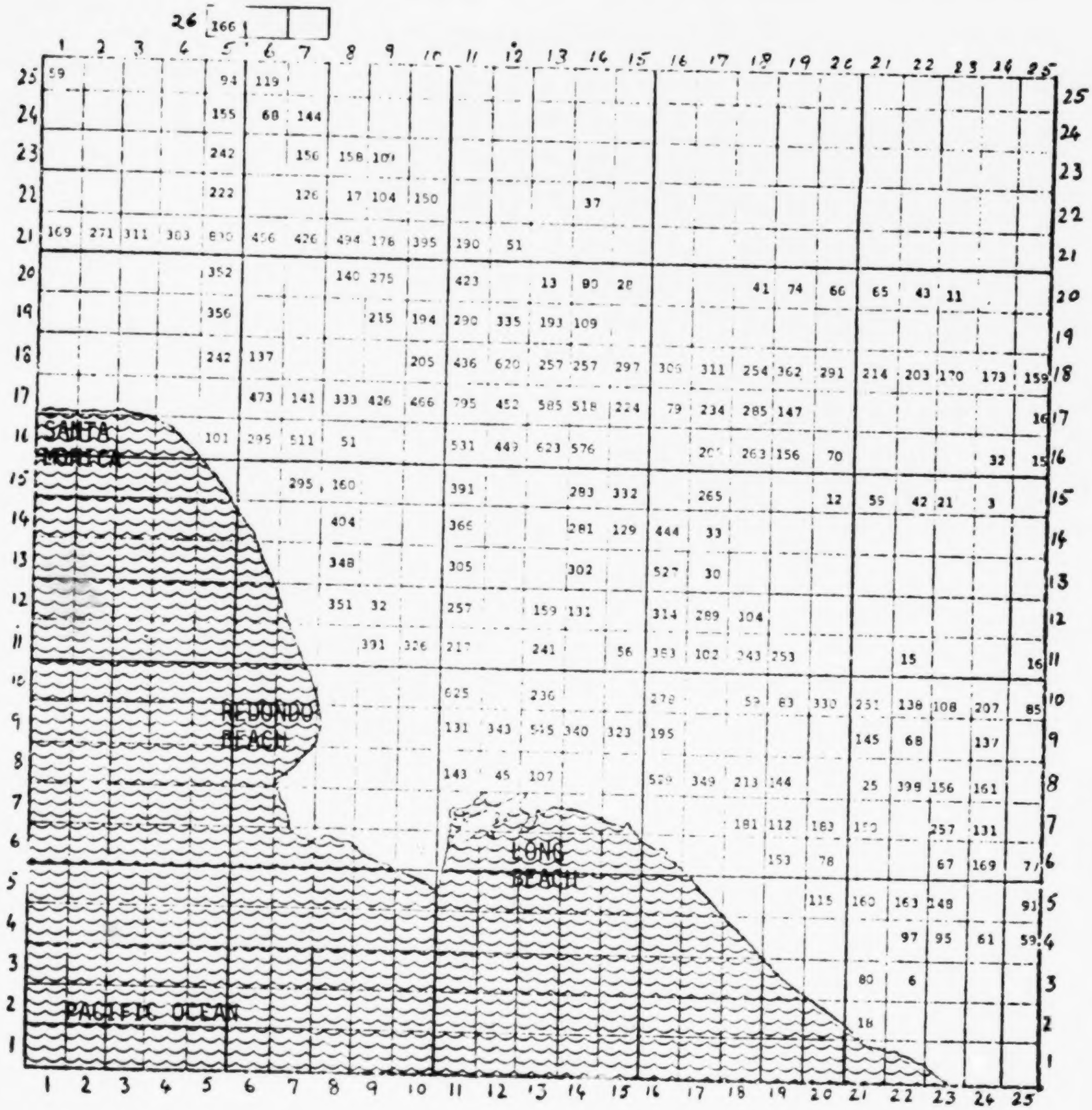
SANTA MONICA
REDONDO BEACH
LONG BEACH
PACIFIC OCEAN

Figure 5.2 Spatial Distribution of Freeway Traffic (thousands of miles/day)

SOURCE: Roberts, P., P. M. Roth, and C. L. Nelson, "Contaminant Emissions in the Los Angeles Basin -- Their Sources, Rates, and Distribution," Appendix A of Development of a Simulation Model for Estimating Ground Level Concentrations of Photochemical Pollutants, Systems Applications Inc., Report 71 SAI-6, March, 1971. p. A-10

Table 5.5 TEMPORAL DISTRIBUTION OF TRAFFIC[a]

Time Period	Percentage of Total VMT	Peak Hour VMT Percentage[b]
Freeways		
12 - 5 A.M.	1.94	
5 - 6 A.M.	0.89	
6 - 7 A.M.	2.96	10.04
7 - 8 A.M.	3.84	
8 - 9 A.M.	3.24	
9 -10 A.M.	2.68	
10 - 2 P.M.	9.88	
2 - 3 P.M.	2.85	
3 - 6 P.M.	11.19	11.19
6 - 7 P.M.	2.99	
7 -12 P.M.	7.55	
Non-Freeways		
12 - 6 A.M.	2.04	
6 - 7 A.M.	1.46	7.97
7 - 9 A.M.	6.51	
9 -11 A.M.	5.02	
11 - 4 P.M.	6.22	9.44
4 - 6 P.M.	8.20	
6 - 8 P.M.	5.40	
8 -12 P.M.	6.16	

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[a] Assumes 50 percent of the total VMT attributable to freeway traffic (see Table 2)

[b] Defined here as the periods from 6-9 A.M. and 3-6 P.M.

SOURCE: Adapted from Roberts, P., P. M. Roth, and C. L. Nelson, "Contaminant Emissions in the Los Angeles Basin -- Their Sources, Rates, and Distribution," Appendix A of Development of a Simulation Model for Estimating Ground Level Concentrations of Photochemical Pollutants, Systems Applications, Inc., Report 71 SAI-6, March, 1971, p. A-10.

6.0 TRAFFIC FLOW STRATEGIES

In general, traffic flow improvements are not likely to have a significant impact on improving the ambient air quality in the South Coast Air Basin. Better traffic flow and services on surface streets and highways, while an explicit goal of the agencies involved in transportation planning and control, can result in an increase in air pollution emissions if travel included as a result of increased accessibility or ease of travel produces emission increases outweighing emission reductions resulting from traffic movements. Consequently, a strategy to reduce idle time or congestion should be coupled with programs providing negative incentives or restrictions to driving. Combinations of traffic flow programs and VMT reduction strategies, if successfully implemented, offer some hope at reducing emissions.

To assess the impact on air quality from various traffic flow measures, one needs to understand the relationship of speed on emissions. To date, only a limited amount of work has been done in this area.

Rose, et. al (63) examined the impact of speed on emissions in the early 1960's. Forty cars, ranging in age from 1955 to 1963 model years, were tested in the cities of Cincinnati and Los Angeles; all the cars studied were uncontrolled vehicles and consequently, atypical of the majority of cars on the road today. The results indicated that for HC and CO, increased average speed lowered emissions; NO_x emissions appeared to be independent of speed.

More recently, the California Air Resources Board (75) studied the speed versus emission relationship on 5 vehicles, one uncontrolled and four controlled vehicles. Although the sample examined was very limited, the vehicles involved were more representative of the present automobile population. The test results from these cars were averaged and are shown in Figures 6.1 - 6.3. Similar to Rose's study, CO and HC emissions decreased with increasing average speed. However, NO_x emissions increased substantially at higher speeds. This is partly due to the higher compression ratios found in the majority of post-1966 controlled vehicles. The increased NO_x emissions experienced from 1966 through the early 1970's are largely due to attempts to significantly reduce CO and HC within the Basin.

Given the relationships found by the CARB hold, a key consideration for traffic flow schemes or strategies which affect the average vehicle speeds, is that a trade-off is made between lower CO and HC emissions at the expense of increased NO_x and vice versa. The decision of how to improve the air quality with traffic flow measures requires a knowledge of which pollutant(s) needs the greatest degree of control. While it is generally conceded that reactive hydrocarbons must be controlled stringently, it is also felt that controls of NO_x emissions must take place concurrently. A continuing controversy exists in the research community as to which control strategy will be the most effective for improving air quality in the South Coast Air Basin. The experience gained from the 1966-1970 attempts of not controlling NO_x, suggests that the photochemical oxidant problem may not be significantly improved but merely relocated (e.g., from Downtown to Riverside).

In view of the paucity of data relating speed to emissions, it is assumed for the present analysis that the curves (Figure 6.1-6.3)

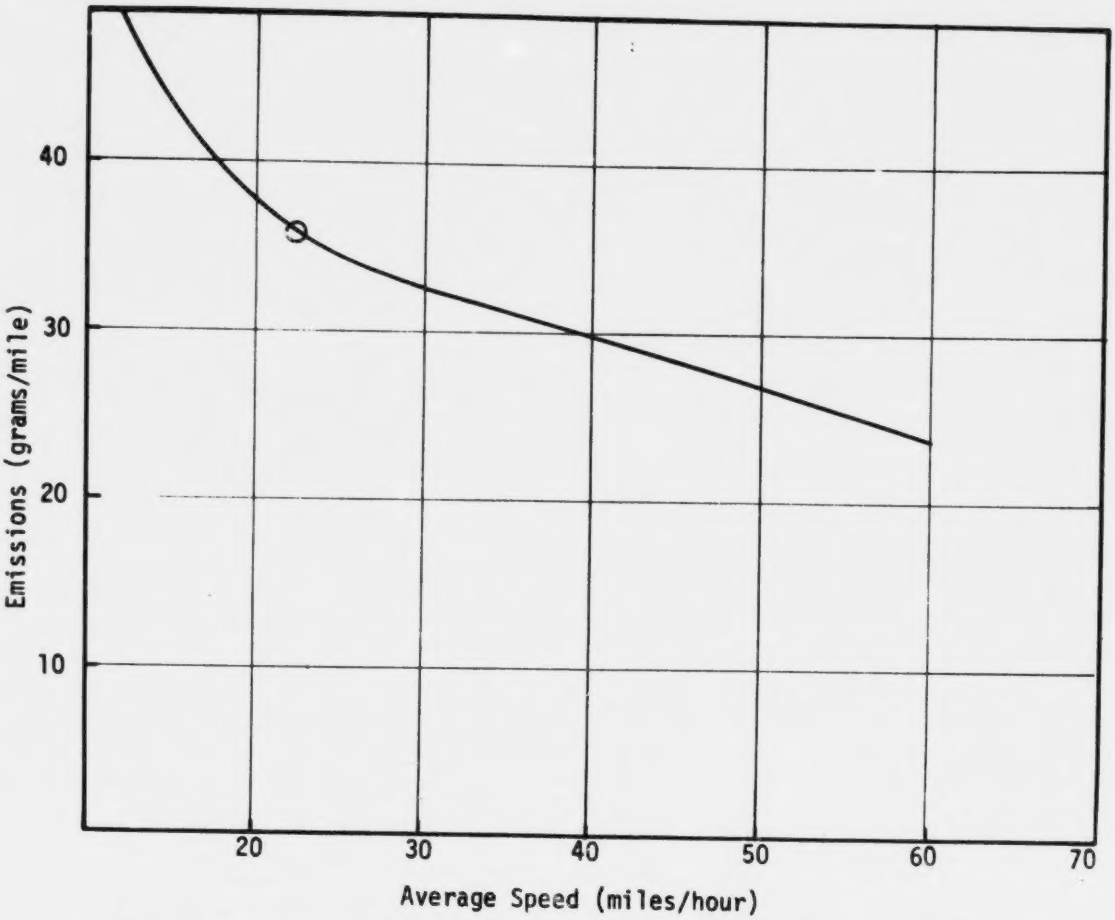


Figure 6.1. Average Speed vs. Average Emissions (Carbon Monoxide).

Source: California Air Resources Board, Project M - 220, "Effect of Speed on Emissions", March, 1971.

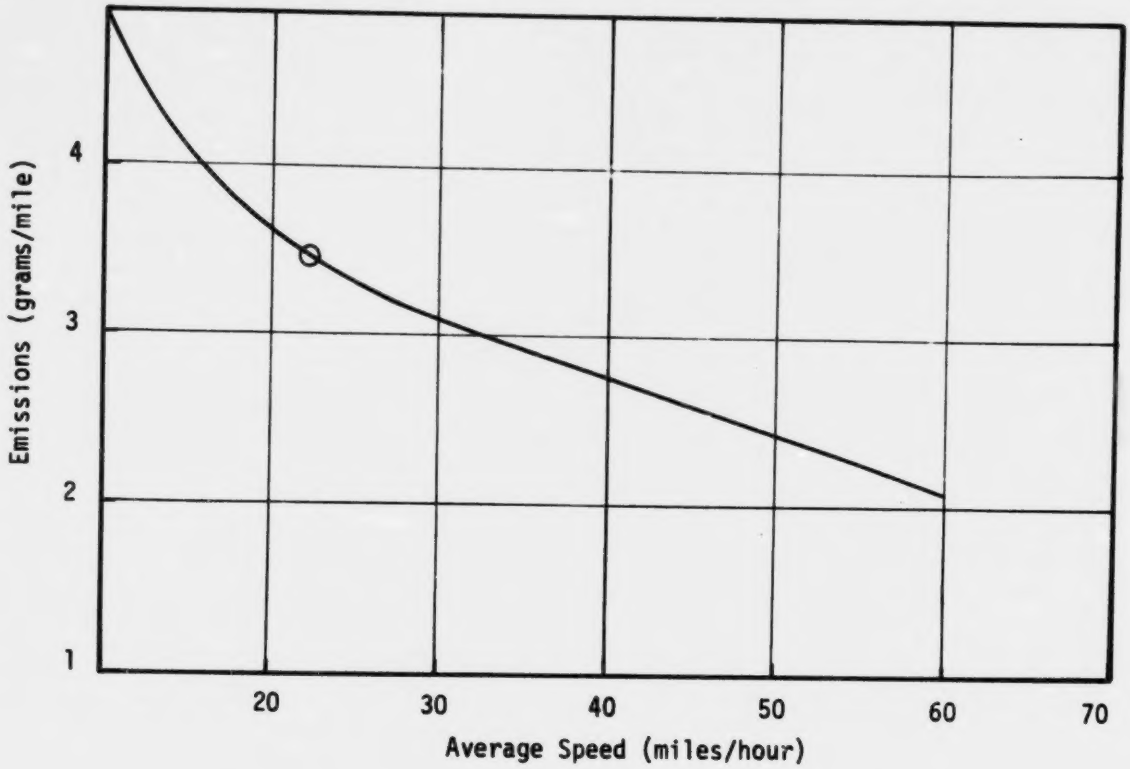


Figure 6.2 . Average Speed vs. Average Emissions (Hydrocarbons)

Source: California Air Resources Board, Project M - 220, "Effect of Speed on Emission", March, 1971.

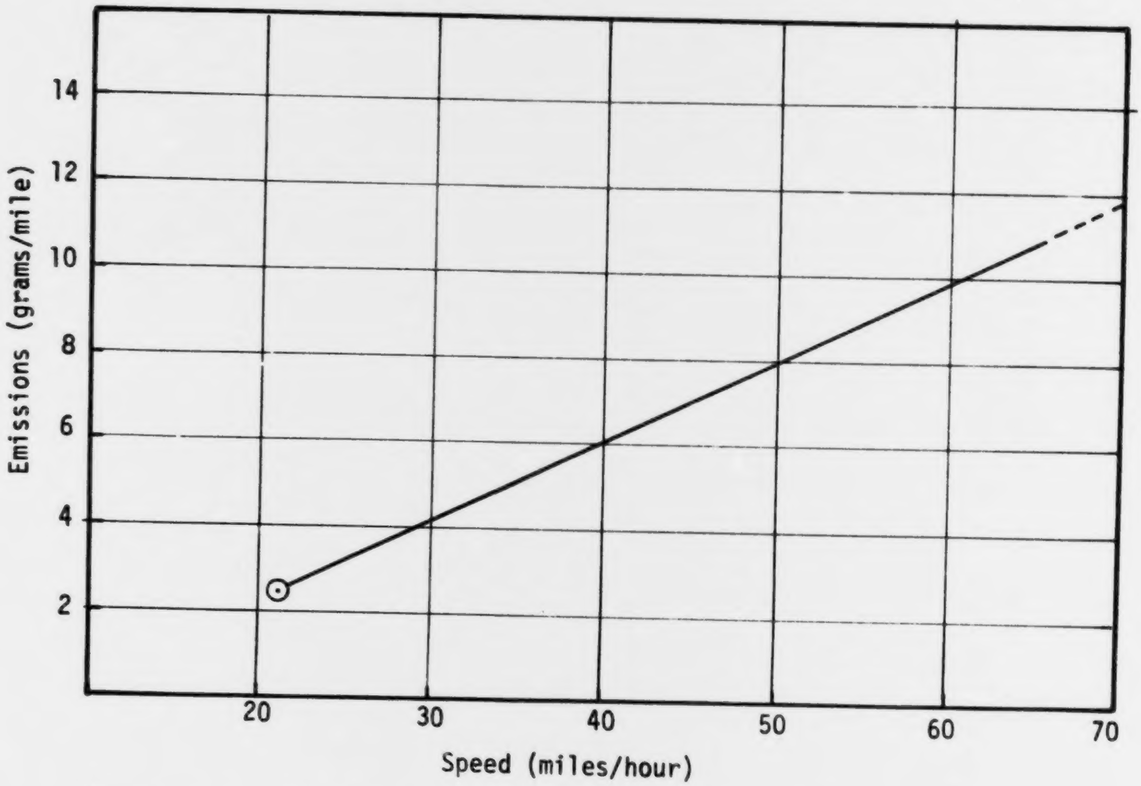


Figure 6.3. Average Speed vs. Average Emissions (Nitric Oxide)

Source: California Air Resources Board, Project M - 220, "Effect of Speed on Emissions", March, 1971.

generated by the CARB are valid. It is recognized that as newer vehicles enter the automobile population, significant changes in the effect of speed on emissions are likely to occur. Also, with the addition of various retrofit devices, e.g., vacuum spark advance disconnect, the older vehicles are likely to experience a change in their emission characteristics, including the emission levels associated with various average speeds.

6.1 Impact of Presently Proposed Traffic Improvement Programs

City and County governments are generally responsible for controlling traffic on the city street system. There are 127 cities and 5 counties contained in the LARTS study area,(15) the City of Los Angeles being by far the largest municipal organization in the study area.

In an interview with the City Traffic Engineer of Los Angeles(91) it was estimated that through the current 5 years capital improvement programs and through future TOPICS programs, the average speed of travel on city streets could be raised 2.5 miles per hour from the current average speed of 21.2 miles per hour.(43) The probable impact on emissions from such a small increase in average speeds is likely to be minor. The intent of currently projected programs is to improve service and flow; minimizing the vehicular emissions has not been an explicit goal of the local traffic departments.

Two major responsibilities of the California State Division of Highways are planning for highways and improving the present levels of service provided by them. A substantial effort is directed towards minimizing the total delay experienced by users of the system. Programs to accomplish this goal include:

1) completion of the planned freeway network,

2) removal of existing bottlenecks through addition of capacity and ramp metering,

3) freeway surveillance techniques to detect and remove unusual incidents, and

4) improved motorist information systems.

The impact of completing the freeway network will be an increase in total vehicle miles of travel and a shift in the distribution towards increased freeway travel. This impact is already accounted for in the 1977 VMT projections. Table 6.1 shows the growth of freeways in the Basin since 1950. This growth has resulted in the steady increase in freeway VMT.

The removal of existing bottlenecks and ramp metering is part of a 10-year program presently underway by District 7 and will be approximately 70 percent complete by 1977.(18) All of the first stage improvements which will be coordinated with ramp controls, will be completed by 1977.

The stated aim of this project is to maintain traffic flow at or above 50 miles per hour during the peak hours. In a 1971 study of freeway travel time from the Los Angeles central business district, the average speed during the most congested time periods was 36 M.P.H. with an 18-50 M.P.H. range.(14) Since the fraction of VMT on freeways at speeds less than 50 M.P.H. account for a small percentage of VMT in the Basin (see Impact of a 55 mph Speed Limit...), the impact of traffic flow improvements will be a slight decrease in HC and CO emissions with an accompanying increase in NO_x emissions. The impact on overall air quality is expected to be very minor.

Table 6.1. Miles of Freeways, Five-County Los Angeles Metropolitan Area (Los Angeles, Orange, Ventura, Riverside, San Bernardino)

Year	Miles
1950	49.8
1951	63.3
1952	91.2
1953	105.5
1954	130.8
1955	161.9
1956	179.1
1957	200.0
1958	230.0
1959	282.5
1960	301.4
1961	329.9
1962	336.8
1963	374.9
1964	431.3
1965	456.2
1966	500.6
1967	540.7
1968	579.0
1969	623.5
1970	645.2
1971	695.1

Source: Branch, M. C. and E. Y. Leong (eds.), Research Investigation - Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972, p. G-12.

6.2 The Impact of Ramp Metering of the Freeway System on the VMT in the Basin

As alluded to previously, the Division of Highways is presently engaged in expanding its ramp metering program. Currently, a select number of sites are metered; this is done primarily during the rush hour in an attempt to regulate flow and minimize congestion. One might expect a diversion of traffic from the freeways onto the city streets due to ramp metering; this effect has been negligible on the Harbor Freeway,(53) where instead, it was found that the motorists actually entered the freeway upstream of the metering, thus increasing the freeway VMT.

It is difficult to generalize from the limited experience of the present metering projects. However, from surveys of users of the controlled ramps, it seems likely that a temporal dispersion of peak hour traffic will occur first, rather than diversion to city streets.(88)

An additional impact of ramp metering will be the increase in idle times while waiting on the ramps. Present wait time on metered ramps average 8 minutes during the most congested traffic periods.(53)

Presently, buses are given priority for entrance onto the freeway at controlled ramps during peak hours by means of a bus bypass lane. This effectively gives the bus an eight minute travel time reduction relative to the automobile travel time. Thus far, this slight advantage has had little effect in diverting the commuters from their automobiles.

The initial experience of motorists' attempts to circumvent the Division of Highway ramp meters by alternate routes or modified entering times would imply any expanded versions of the metering program are likely to induce an alteration of temporal and spatial distribution of the VMT, rather than a significant reduction in travel. The initiation of a direct regulatory program such as controlling every access point onto the freeway system through ramp metering is very likely to induce the following responses:

1) increase the idle time of motorists willing to wait to get onto the freeway; this will be induced by the guarantee of a relatively rapid flowing, congestion free ride once onto the freeway,

2) adjustment of work schedules, i.e., voluntary staggering of work hours, in an attempt to avoid travel in the peak congestion time periods,

3) diversion to surface streets, primarily along side of, and paralleling many of the existing freeways.

With regard to the last item, given severe enough restrictions for access onto the freeways, the present excess capacity on major surface streets is likely to be used. In conversations with the city traffic personnel, it was estimated that on the average, as much as 30 percent more traffic could be handled on major arteries paralleling freeways during peak traffic periods. Table 6.2 presents volumes and capacities for a number of surface streets paralleling the freeways; for the streets listed, anywhere from 19 to 50 percent more traffic capacity was available during the peak traffic flow.

With extensive ramp metering, one can expect commuters will find the path of least resistance in order to get to work. Only if they encounter significant restrictions in the alternative routes are they likely to opt for an alternative mode of transportation, such as the bus. A more

TABLE 6.2

CURRENT VOLUMES AND CAPACITIES ON SELECTED ARTERIALS IN THE LOS ANGELES AREA

Location[a]	Morning Peak Hour Volume (vehicles per hour)	Capacity[b] (vehicles per hour)	Excess[c] Capacity
Washington Blvd. @ Western Ave.	933	1200	29%
Figueroa St. @ Slausen Ave.	1527	1800	19%
Ventura Blvd. @ Van Nuys Blvd.	1006	1200	20%
Sunset Blvd. @ Alvarado St.	1197	1800	50%

a -- sites selected are all major arterials which parallel existing freeways.

b -- based on an estimated capacity of 600 vehicles per lane per hour for urban arterials.

c -- computed as the difference between observed volumes and capacity as a percentage of observed demand.

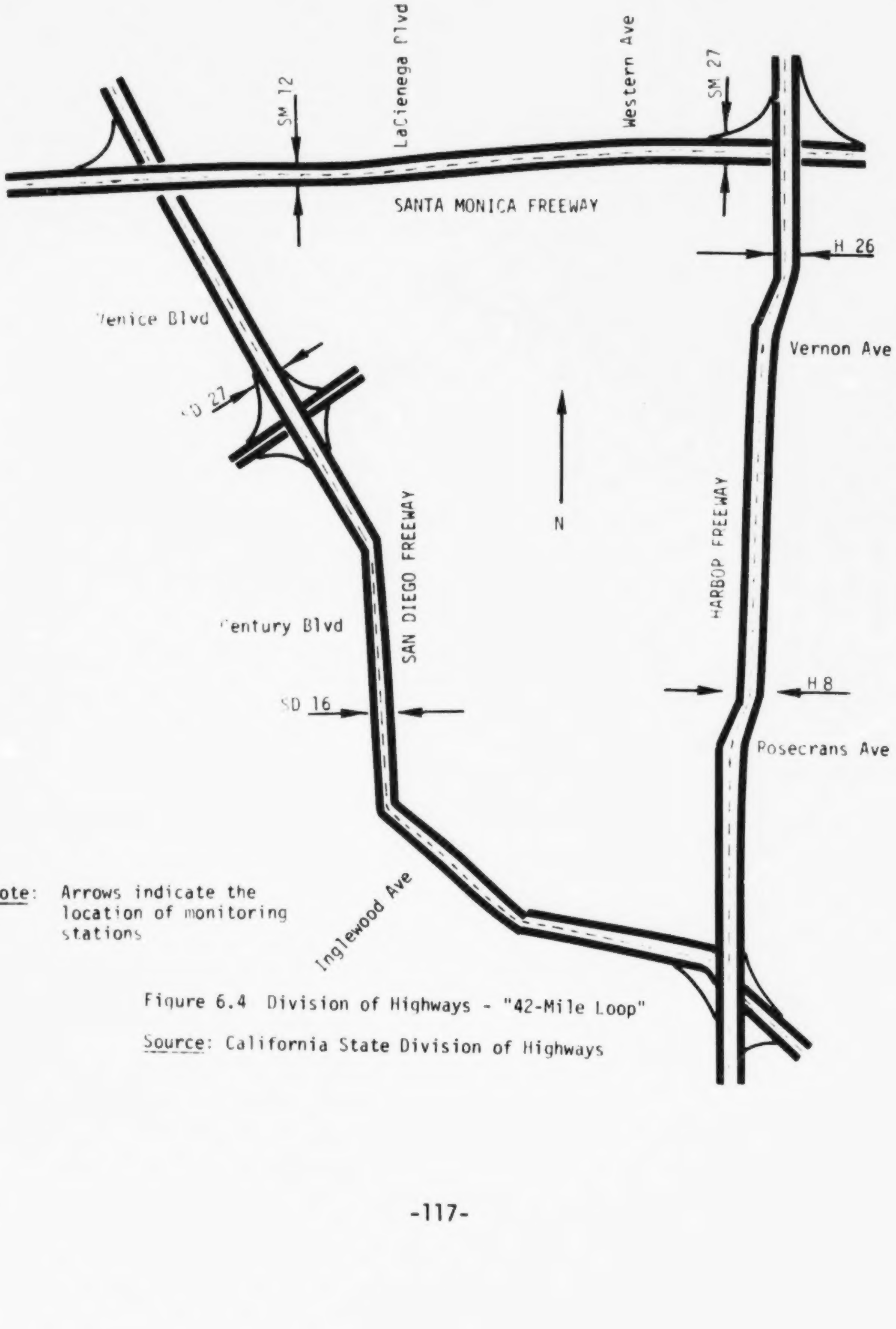
Source: City of Los Angeles Traffic Department, 1972 Traffic Counts detailed analysis of demand elasticities for the critical travel variables will be examined later in the report.

6.3 The Impact of a 55 M.P.H. Speed Limit in the South Coast Air Basin

Currently, travel on the freeways accounts for approximately 50 percent of the Basinwide VMT. A large fraction of the miles travelled on freeways is at or near the maximum speed limit, i.e., 65-mph. In light of the high emissions of nitrogen oxides at these speeds an examination was made of the trade-off in emissions which would result from a program which would lower the Basinwide speed limit to 55 M.P.H.

The Freeway Operations Division of the District 7 office of the of the State Division of Highways is involved in a series of programs on a 42-mile loop of freeways in Los Angeles. On Thursday, October 12, 1972, the Freeway Operations Division compiled, speed and volume counts at six sites over a fourteen hour period (5a.m. to 8p.m.). Figure 6.4 shows the freeways involved and notes where the monitors were located. All lanes at the six sites were monitored. Two stations were used on each of the three freeways involved in making up the 42-mile loop. From an examination of the freeway operating characteristics reported in the Inventory of Freeway Geometric Bottleneck Congestion First Interim Report, it was concluded that each station was representative of approximately one-half the length of the freeway segment. Consequently, vehicle miles were computed by multiplying the volumes at the station times one-half the freeway length.

The volumes not covered by the survey were obtained from 1971 traffic counts taken by the State.(13) The volumes for the surveyed hours were subtracted from the average annual ADT. It was assumed that the


LaCienega Blvd
Western Ave
SM 12
SM 27
SANTA MONICA FREEWAY
H 26
Venice Blvd
Vernon Ave
SD 27
N
SAN DIEGO FREEWAY
HARBOR FREEWAY
Century Blvd
SD 16
H 8
Rosecrans Ave
Inglewood Ave

Note: Arrows indicate the location of monitoring stations

Figure 6.4 Division of Highways - "42-Mile Loop"

Source: California State Division of Highways

Table 6.3

Vehicle Miles Travelled - "42-Mile Loop"
(October 12, 1972)

Monitoring Station	VMT
San Diego Freeway	
Station #16	1,365,850
Station #27	1,549,575
Santa Monica Freeway	
Station #12	1,137,482
Station #27	1,076,573
Harbor Freeway	
Station #8	871,535
Station #24	1,234,190
Total	7,234,205

Note: The total VMT on the 42-mile loop represents approximately 10 per cent of the total freeway VMT for the Basin

Source: Calculated from volume and average speed data provided by Freeway Operations Division, District 7, Division of Highways

In calculating the impact of a change in freeway speed to 55 mph the following assumptions were made:

1) the fraction of VMT at 65 mph or greater would all become 55 mph or greater,

2) the fraction of VMT at 60-65 mph would allocate equally to the 55 mph or greater and 50-55 mph categories,

3) the fraction of VMT at 55-60 mph would all become 50-55 mph

average speed for these hours was 65 M.P.H. It was further assumed that through the course of a day, the daily VMT in opposing directions were equal.

Figures 6.5 - 6.10 give a detailed breakdown of the fraction of VMT travelling within a given speed range. By incorporating the actual VMT figures for each freeway leg of the 42-mile loop (Table 6.3), one obtains the number of miles travelled through the day as a function of speed. Applying the emission factors derived by the CARB allows one to calculate directly the emissions released.

Of primary interest is the relative trade-offs associated with such a program. Since the fraction of total VMT which occurs on freeways is approximately 50 per cent, one can directly calculate the Basinwide emission impact from motor vehicles. This assumes, of course, that the freeway VMT on the 42-mile loop are representative of the freeway VMT throughout the rest of the Basin. Conversations with personnel from the Freeway Operations Division indicate that this is, in fact, a very reasonable assumption.

Implementation of this strategy does not appear to be a major problem; the key issue to be resolved is whether an 8 per cent reduction in NO_x emissions accompanied by a 2.5 per cent increase in hydrocarbons is a reasonable trade off. The establishment of speed limits on the freeways is a responsibility of the Division of Highways; enforcement falls under the jurisdiction of the California Highway Patrol. Should the program be implemented, one can initially expect frequent violations because of current driver habits. Rigorous enforcement of the new speed limit would very likely be necessary.

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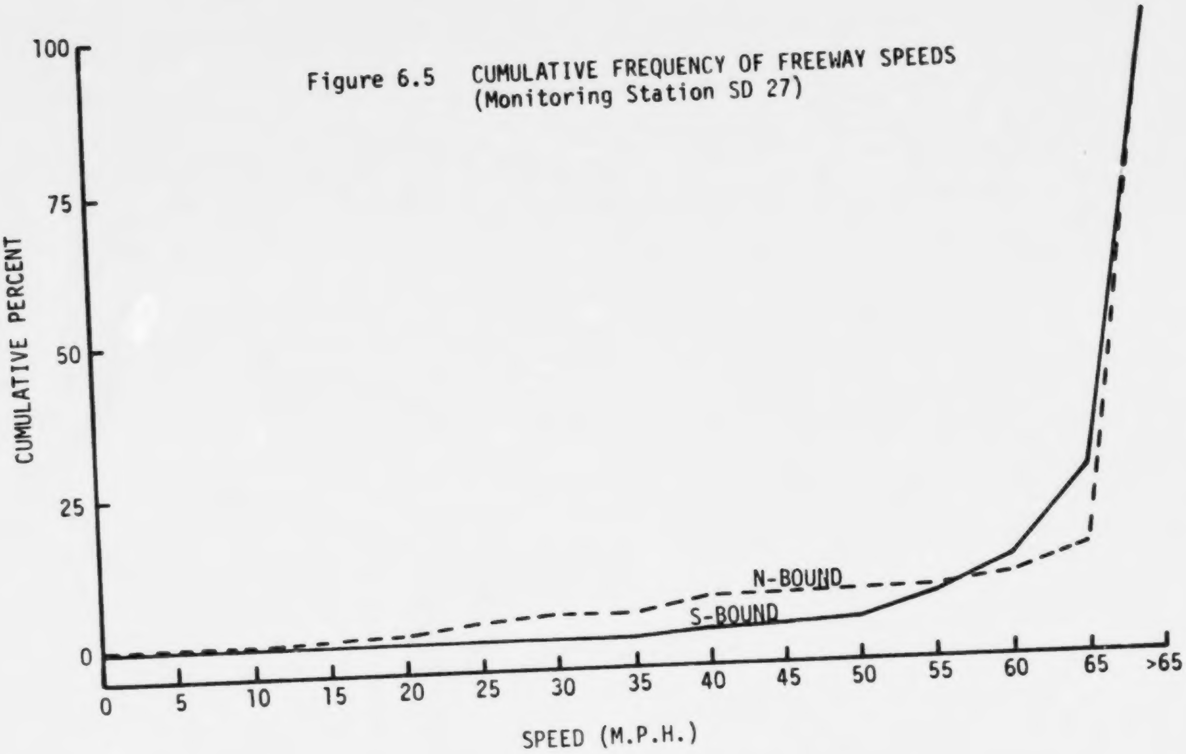


Figure 6.5 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS (Monitoring Station SD 27)

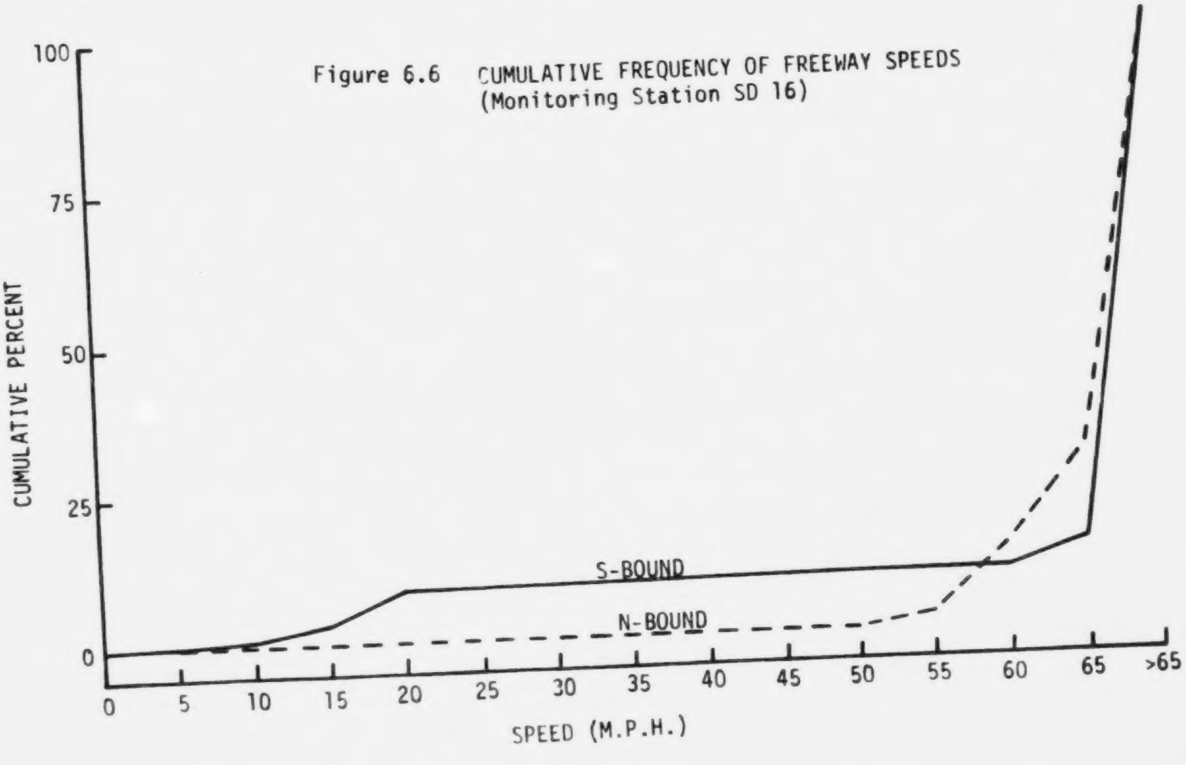


Figure 6.6 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS (Monitoring Station SD 16)

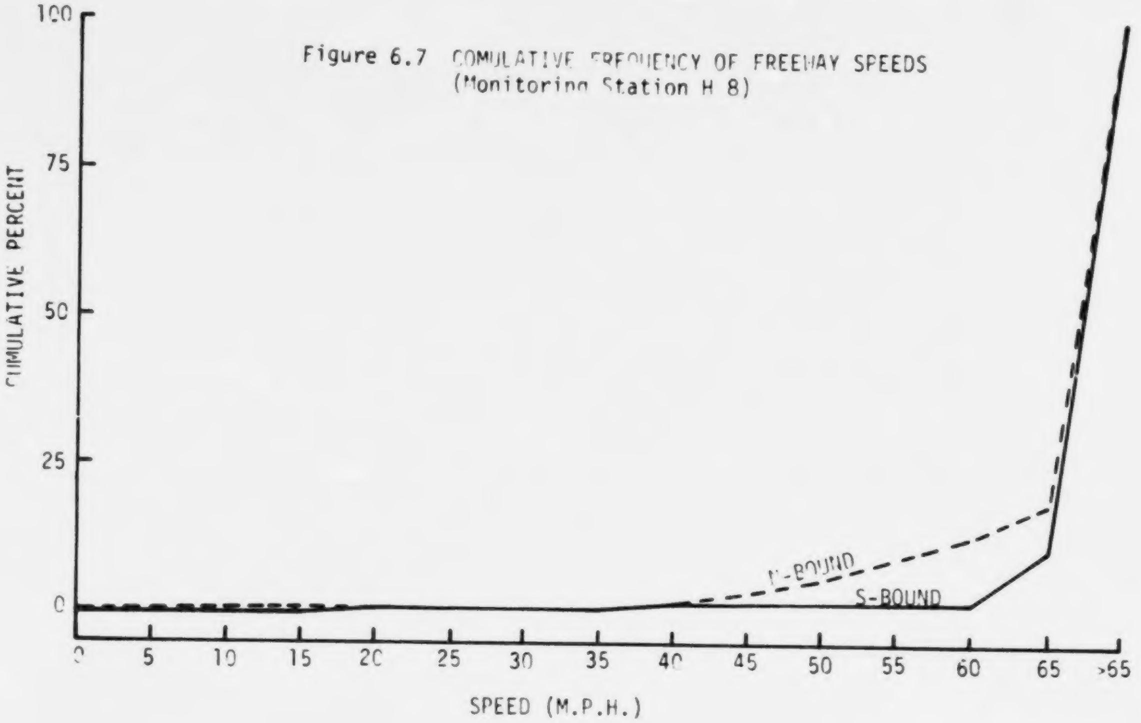


Figure 6.7 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS
(Monitoring Station H 8)

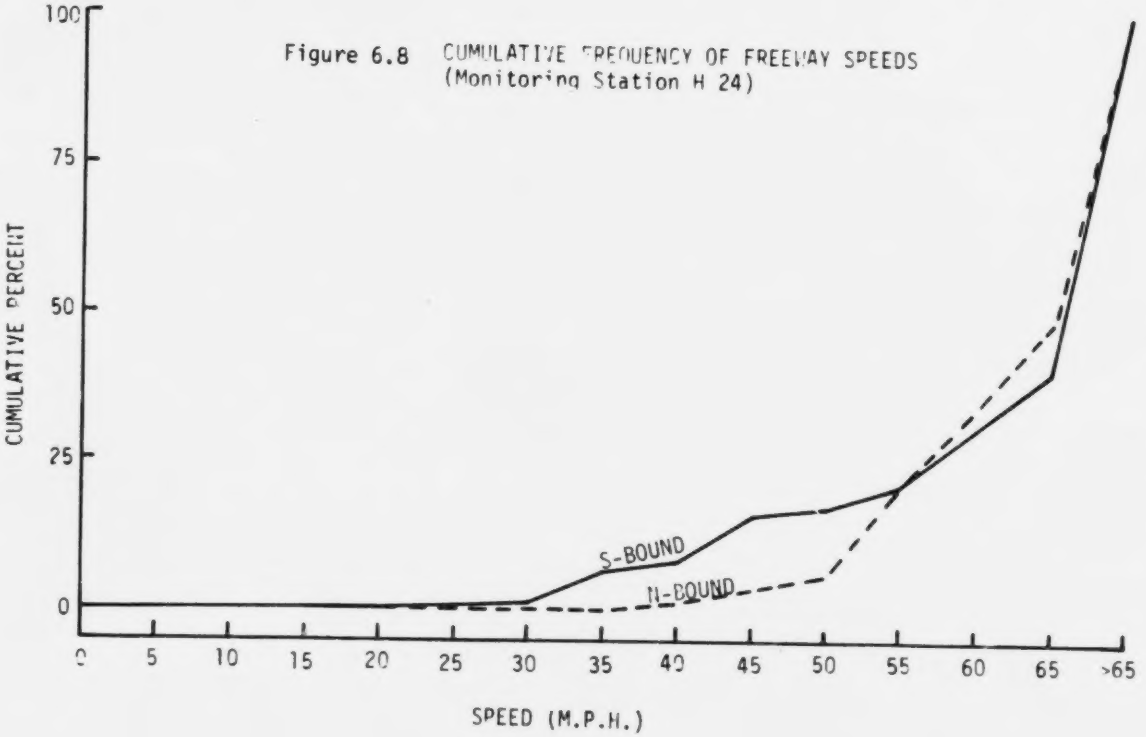


Figure 6.8 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS
(Monitoring Station H 24)

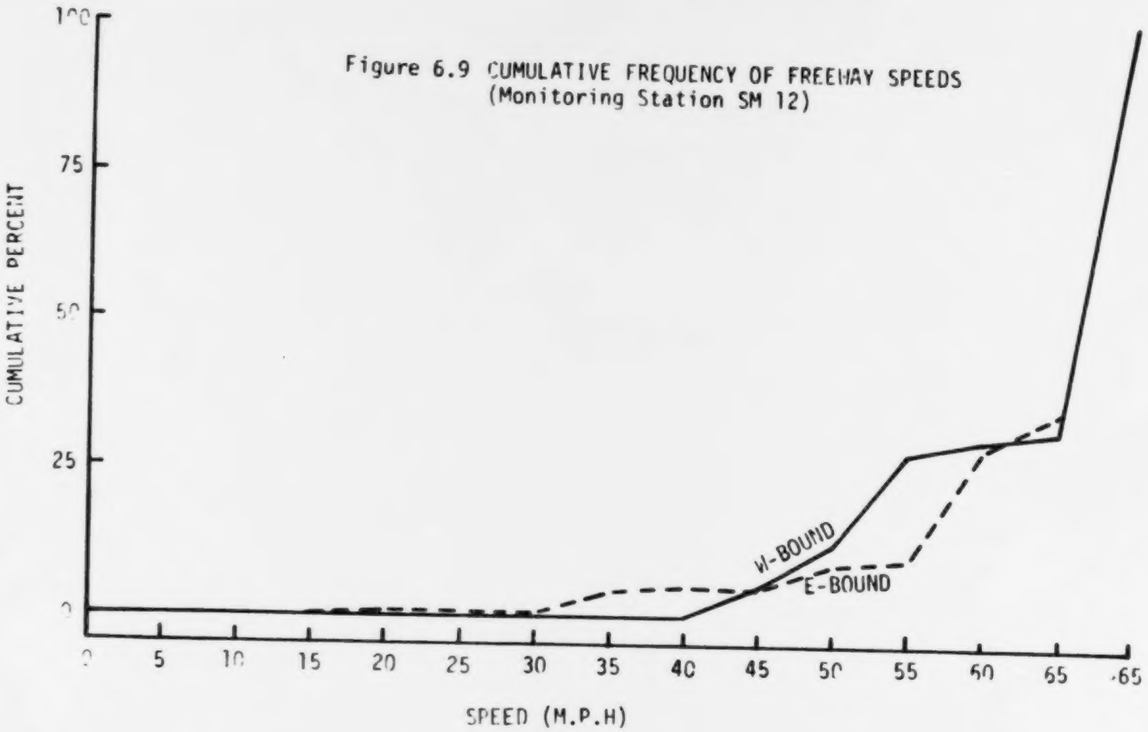


Figure 6.9 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS (Monitoring Station SM 12)

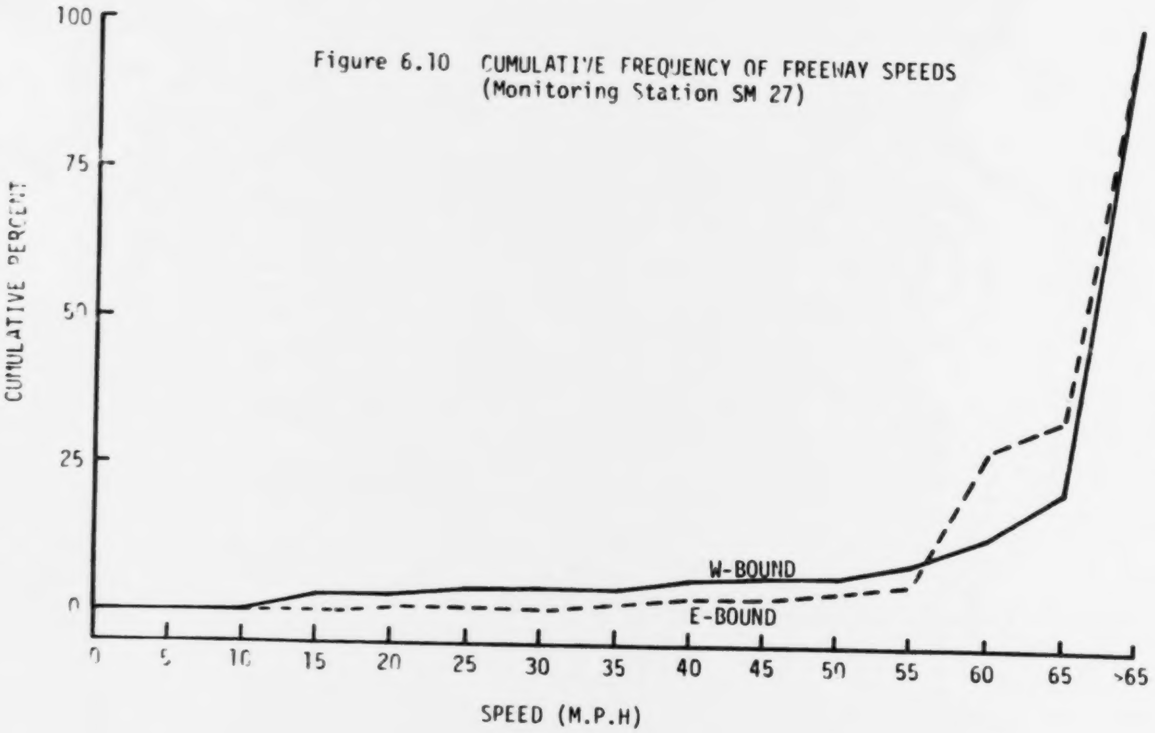


Figure 6.10 CUMULATIVE FREQUENCY OF FREEWAY SPEEDS (Monitoring Station SM 27)

Table 6.4

Relative Emission "Trade-Offs" Associated with a 55 MPH Speed Limit

	HC	CO	NO_x
Freeway VMT	+5.0%	+4.7%	-16%
Basinwide VMT	+2.5%	+2.4%	-8%

Assumptions:

1) CARB emission rates as reported in Project M-220 "Effect of Speed on Emissions", March, 1971
2) 42-mile loop of freeways is representative of Basinwide freeway travel
3) 50% of total VMT in the Basin is on freeways

In view of the nature of the photochemical oxidant problem, two variations of the 55 M.P.H. speed limit control should be examined in more detail:

1) institution of a 55 M.P.H. limit only during the peak smog season, i.e., April through October; a close analogy would be the LAAPCD rule governing fuels to be used during specific seaons according to their air pollution potential.
2) institution of 55 M.P.H. limit during the daylight hours (e.g. 6 A.M. to 6 P.M.) to lower the reactive emissions available for photochemical transformations. A variant of this would be to apply this during the high smog months mentioned above.

Both strategies are an attempt to attack the interim nature of the problem and to minimize the lifestyle disruption element.

6.4 The Impact of Staggered Work Hours

The intent of staggered work hours is to disperse peak traffic periods and temporally redistribute the VMT. No VMT reduction can be expected from such a program; if anything, the improved traffic flow may induce additional travel. The perception of freer flowing traffic and real changes in accessibility could activate latent travel demand, although such activation normally results from major accessibility shifts produced by new facilities rather than from marginal changes associated with various forms of flow improvements.

Even if the potential for induced VMT increases is discounted, staggered work hours appear to have little value as a control strategy for the Los Angeles Basin.

Staggered work hours can be effective in dispersing peaking if the employment concentration is reasonably representative of a point source loading traffic onto a set of routes radiating from it. However, in the Los Angeles area employment activity is highly dispersed and could be best characterized as line sources loading traffic at continuous points along the major travel arteries. With such an employment activity configuration, peak commute traffic is automatically temporally and spatially dispersed over the street and highway system without the aid of staggering attempts. In fact, under such conditions staggering could result in increased peaks of traffic demand at some points on the system.

If flow improvements were achieved as a result of staggered work hours, only marginal gains in terms of emission reductions could be anticipated. Most of the increased speeds which would result would be in speed ranges above the below 20 M.P.H. high leverage area for achieving emission reductions through speed increases (see Figures 6.1 and 6.2).

Moreover, the emission reductions in CO and HC achieved through higher speed operations are gained essentially in a trade-off with increased NO_x emissions at the higher speeds.

The impact of temporal and spatial redistribution of work-trip related vehicular emissions is difficult to assess. Ideally, one would have an analytical model which incorporated the temporal and spatial emission patterns with the meteorological parameters and the photochemical reaction processes. In the absence of such a simulation model, attention must be given to factors which result in photochemical smog and how they are affected by a time change.

The tonnage of automative emissions remains essentially unchanged in a staggered work hours situation. However, since the extent of photochemical activity is a function of solar intensity and the concentration of reactive precursors, a change in where and when maximum air pollution levels will occur is likely. Figure 6.11 shows an example of the different times at which maximum oxidant levels occur in various parts of the Basin.

The question of how and where pollutants are transported within the region is a subject of continual controversy. Several studies have examined the transport of pollutants by winds. Most meteorological data confirm the prevailing wind patterns coming from the west and blowing eastward during the peak smog periods. Figure 6.11 strongly suggests oxidants are transported eastward during the course of a day. Therefore, depending on how work hours were staggered, one might expect

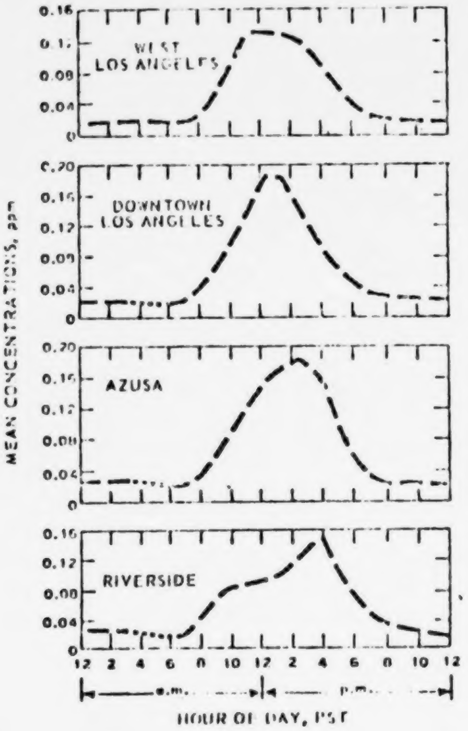


Figure 6.11 Diurnal Variation of Mean 1-Hour Average Oxidant Concentration at Selected California Sites, October, 1965

Note: West Los Angeles is approximately 10 miles west of Downtown L.A. Azusa is roughly 20 miles east of Downtown and Riverside is about 30 miles east of Azusa.

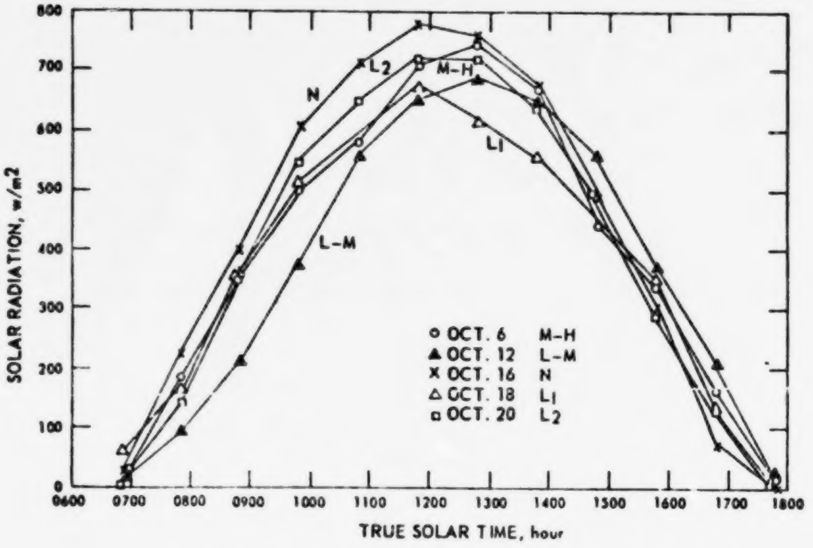
Source: Department of Health, Education, and Welfare, Public Health Service, Environmental Health Service, Air Quality Criteria for Photochemical Oxidants, AP-63, March 1970.

an earlier or later oxidant peak. For example, if the present 6-9 A.M. period was spread out over a 6-11 A.M. period, one might expect a higher oxidant value to occur at the same time or the maximum oxidant peak to occur slightly later in the day than normal. The increased oxidant value might result from two factors:

1. More intensive photochemical activity due to increased solar radiation later in the morning (Figure 6.12).
2. Increased tonnage of reactive pollutants from increased VMT.

In summary, staggered work hours seems to be an unpredictable control strategy which could result in a more severe photochemical oxidant problem. Under the appropriate meteorological conditions, one could expect either a spatial or temporal shift in the presently experienced oxidant levels. Equally important, staggered work hours tends to discourage car pooling since there are fewer commuters with common work schedules.

Figure 6.12 Average Solar Radiation Measured with Pyranometer for 1-Hour Intervals in L.A.



Source: Nader, J.S. (ed.), Pilot Study of Ultraviolet Radiation in Los Angeles-October, 1965, U.S. Department of Health, Education, and Welfare, Public Health Service, 1967, p. 89.

7.0 VMT REDUCTION PROGRAMS

This section deals with control strategies aimed at reducing the total VMT in the South Coast Air Basin. As such, they are programs which attack the source of the problem directly. Any reductions in VMT will result in lowered emissions and a corresponding improvement in air quality. Basically, strategies should be aimed at increasing the number of person trips per vehicle through incentives for car pooling and public transit, restricting automobile usage, reducing the number of daily person trips, and minimizing the distances of typical trips.

Currently, the level of public transit ridership in the South Coast Basin is low. An examination of the percentage of workers who use public transportation in a number of large metropolitan areas shows Los Angeles ranking very near the bottom (Table 7.1). Existing land use patterns, typically low density with highly dispersed employment activity and no real focal concentrations, engender travel patterns which cannot be well served by conventional bus or existing forms of rapid transit. This has precluded development of efficient, economic public transportation systems capable of serving divergent travel demands of Basin residents on a large scale. Consequently, when residents of the Basin are questioned about transit, their responses citing unavailability of service, inconveniently located routes and stops, and slow travel speed (see Appendix F), reveal their perception of the problem which results from the area's dispersed land use and travel patterns.

Table 7.1. Per Cent of Workers Using Public Transportation, 1960 (Bus and Rapid Rail Transit)

Area	Urban Fringe	Total Area
Los Angeles, CA	4	8
New York, N.Y.	22	45
Chicago, Ill.	18	31
Philadelphia, PA	17	31
San Francisco, CA	9	19
Boston, Mass.	18	24
Washington, D.C.	13	24
Dallas, TX	3	12
San Diego, CA	3	7

Source: Wilbur Smith and Associates, Transportation and Parking for Tomorrow's Cities, The American Automobile Association, 1966.

Figure 7.1 presents transit percentages of total person travel corresponding to percent reductions in daily VMT. Derivation of the curves is detailed in Appendix E, Sample Calculation #1. Table 7.2 presents percent transit mode split (either total daily or total commute) required to achieve specified total daily VMT reduction goals.

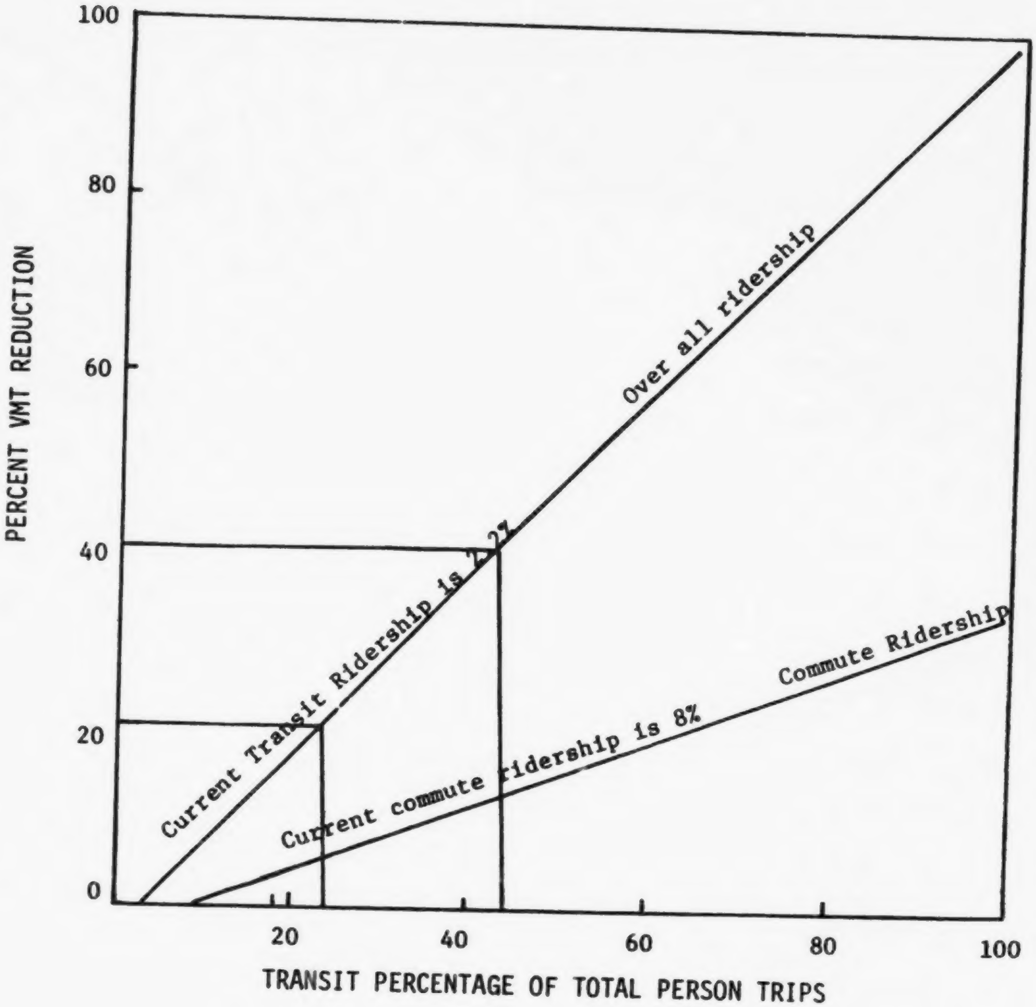


Figure 7.1 VMT Reduction vs. Transit Ridership

Table 7.2. Fraction of Transit Ridership Required to Obtain Various % VMT Reductions

% Overall Transit Ridership	% Commute Transit Ridership	% VMT Reduction
2.2 (current)	8 (current)	0
13	38	10
24	66	20
35	98	30
46	--	40

Assumptions:

1) No change in level of carpooling

2) No change in trip demand: reduced auto-person travel replaced by transit travel on 1 to 1 basis.

7.1 The Impact of Presently Planned Programs

The following summarizes ongoing public transit programs in the South Coast Air Basin.

7.1.1 Public Transportation Organizations

In the South Coast Air Basin the principal planning organization and operator of public transportation is the Southern California Rapid Transit District (SCRTD). However, by 1977 the newly formed Orange County Transit District (OCTD) will also have a significant role in providing and planning for public transportation in the Basin. A third major public transportation organization in the Basin is the Yellow Cab Company of Los Angeles.

7.1.2 Southern California Rapid Transit District (SCRTD)

Presently, SCRTD has two major projects that are likely to have an impact on emissions in the Basin. These are the SCRTD Mini-bus Project and the San Bernardino Busway Project. In addition, feasibility studies are underway by SCRTD with OCTD for park and ride facilities along the Santa Ana Freeway. SCRTD has not as yet defined directions for utilization of the $43 million in Mills-Alquist-Deddeh Act (SB325) funds earmarked for it.

The Mini-bus Project currently uses 19-CNG-propelled buses, each having a capacity of 20 persons. Current operation is between the hours of 9 A.M. to 4 P.M. in the 6 square mile downtown area. A few buses are used during the peak hours to provide a shuttle service for peripheral parking to the Los Angeles Convention Center Parking Lot.

The stated intent of the Mini-bus Project is to reduce private auto use in the downtown area. According to an SCRTD official (89) the Mini-buses have not been successful. Most of the daytime passengers who have taken advantage of the service have been diverted from the pedestrian mode rather than the automotive mode; the peripheral parking scheme has apparently leveled off to a point where only 600 vehicles per day park at the Convention Center. Presently there are no plans to extend the Mini-bus operation to other areas of the city; however, there is talk about studying the feasibility of peripheral parking in Dodger Stadium. This would have negligible emissions impact as will be discussed later (see Impact of Auto Free Zones). Under the most optimistic projections, one would still reduce VMT by less than 0.1 per cent (Appendix E, Sample Calculation #3).

The San Bernardino Freeway Express Busway will be an 11 mile long exclusive bus lane built in the median of the San Bernardino Freeway from El Monte to central Los Angeles. The Busway, expected to be operational by 1974, will have park-and-ride facilities in El Monte and at a midpoint station. At least two on-line stations will also be serving California State University at Los Angeles and the Los Angeles County-USC Medical Center. In the downtown area, the bus will travel on city streets serving the Greyhound Bus Terminal, the CBD, and the Wilshire corridor to Western Boulevard. The buses will have exclusive rights only on the Busway and will compete with other traffic on the surface streets.

Preliminary estimates of patronage project 17,000 daily passengers in 1974 (68). According to an SCRTD official (89) approximately 50 per cent of the 1974 riders will be new; the remainder would be existing transit riders diverted from surface bus routes to the freeway express service. Projecting the 1977 ridership is very speculative at this point because the attractiveness of systems of this type in the Los Angeles travel context is unknown. Public transit ridership on surface routes in the Busway corridor has not grown for five years(89). Therefore, public acceptability, which normally is a function of the auto/bus travel time ratio, will be the prime determinant of the growth rate. The buses' exclusive lane travel advantage does not extend all the way to downtown L. A. The Busway terminates two miles from the downtown area, and as currently planned, buses will travel this final segment in mixed traffic. SCRTD is currently negotiating with the City of Los Angeles for exclusive lanes on surface streets, but the outcome at this time is uncertain. If plans for improved bus flow on the surface street segment of the route can be developed, the San Bernardino Busway Project may possibly be as effective as Shirley Highway Busway project which serves Washington, D. C. commuters. Growth on that system during the first two years of operation has been a function of supply rather than demand (54). During the period from September 1971 to September 1972, demand on the Shirley Highway Busway increased by 50 percent.

Assuming a 50 percent annual growth rate for the San Bernardino Busway project, ridership would be 57,800 passengers per day in 1977 for a reduction of 635,000 daily vehicle miles of travel; this amounts to approximately 0.4 percent of the total VMT (See Appendix E, Sample Calculation #4). However, caution must be exercised in projecting effectiveness of transportation systems for Los Angeles on the basis of experience in other areas. Heretofore, experience with Busways has been in linking low-density residential areas to intense CBD activity concentrations. Despite the fact that one end of the San Bernardino Busway will be in the Los Angeles CBD, the situation there is one of linking low-density residential areas to a small, relatively low density CBD.

As a result of the San Bernardino Busway, the California Division of Highways has recently adopted a statewide policy to acquire at least one right of way for public transportation on all new urban freeway systems. This policy has little potential impact for the target year of 1977 because the new freeway segments that will be in by then serve corridors of very limited transit potential; consequently,none are currently planned.

7.1.3 Orange County Transit District (OCTD)

The newly formed Orange County Transit District (OCTD) is presently planning future transit services in Orange County; currently service to meet basic need of transit dependent groups is the only service provided. Impact of the existing nine bus-operation on air quality and emissions is too small to quantify.

By 1975, the District plans to be operating a significantly expanded system with 215 buses in service.(90) Expansion plans beyond the 1975 target level are undefined at this time. Assuming that patronage on the buses will be comparable to the SCRTD average of 415 passengers per bus per day(67) and that 20 per cent of the passengers are diverted from automobile trips,(90) one can expect 96,000 vehicle miles reduced based on the LARTS 1967 average automobile occupancy of 1.4(15) persons per vehicle and an average trip length of 7.6 miles per trip.(46) This reduction amounts to less than 0.1 per cent of the projected 1977 areawide daily VMT.

OCTD also plans to implement a dial-a-bus system soon in the City of LaHabra. The scope of the project will be the operation of 5 small buses, with less than 20 percent of the projected riders expected to use the system instead of automobiles. The VMT reduction which can be expected from this project is negligible.

As mentioned earlier, OCTD is also studying the feasibility of coordinating with SCRTD on a park-and-ride express bus service along the Santa Ana Freeway. The potential impact of this project was estimated using modal split curves developed for SCRTD and the State Division of Highways (see Appendix E, Sample Calculation #5) which predicted 30 per cent transit ridership and 8 per cent transit ridership during the peak and off peak hours respectively for an estimated 836,000 vehicle mile reduction or 0.5 per cent of the total areawide daily VMT.

7.1.4 Los Angeles Yellow Cab Company

Present travel by taxi in the Basin represents a very small proportion of the total travel. In 1967, it was estimated 0.1 per cent of all trips were made by taxi in the LARTS study area (15). Due to the limited amount of VMT, it is unlikely that even a much improved taxi service could be expected to significantly reduce VMT. At most, only a fraction of one per cent of the VMT could be affected by the taxis (Appendix E, Sample Calculation #6).

The Yellow Cab Company, the largest taxi operation in the Basin, has been planning many programs to improve their operation. The most significant is a current proposal for a dial-a-bus demonstration project making use of their new computer dispatching capabilities. The scope of the program has not yet been specified; however,even if it is doubled the taxi-cab patronage in the Basin, the resultant reduction in vehicle miles of travel would be negligible.

7.1.5 Summary of The Impact of Presently Planned Programs

Despite planning by many organizations and agencies, it appears doubtful that the presently planned programs will have a significant impact on reducing VMT in the South Coast Air Basin. Many of the calculations in the present analysis have used highly optimistic assumptions The reasoning behind this approach is to emphasize the relatively small impact of the programs. Table 7.3 summarizes the VMT reductions from presently planned programs.

Table 7.3. The Impact of Presently Planned Programs

Program	% Reduction in Total VMT
SCRTD Mini-Bus	< 0.1
SCRTD San Bernardino Busway	0.4[a]
OCTD Expanded Bus Service	< 0.1
OCTD Dial-a-Bus	Negligible
SCRTD-OCTD Park-and-Ride	0.5[a]
Los Angeles Yellow Cab Co. Expanded Service (including dial-a-ride)	< 0.2
	< 1.3

[a] optimistic assumptions used

7.2 Elasticity of Demand for Public Transit and the Los Angeles Mode Choice Model(86)

Tables 7.1 and 7.9 clearly illustrate the almost total dependence of Basin residents for private automobiles as the dominant mode of transportation. Strategies aimed at significant VMT reductions must somehow de-emphasize this firmly established dependence. Such strategies will take the approach of either encouraging car pooling and transit ridership (for example by making them more "attractive"),or discouraging the private use of the auto (for example by economic or time penalties). Another approach is that of direct regulations; this type of scheme will be discussed later.

To evaluate the relative effectiveness of various VMT reduction strategies, it is necessary to have an analytical methodology which can predict the potential transit ridership of average automobile occupancy rates for a set of critical variables. Unfortunately, it is very difficult to quantitate the factors people use to rate the attractiveness of car pools relative to driving alone or riding in a bus. Research on this topic has been limited up to the present. Alan M. Voorhees and Associates are currently conducting studies to determine behavioral characteristics of motorists and car poolers on the Hollywood Freeway in Los Angeles which, hopefully, will result in a more complete understanding of carpool modal split.

The parameters affecting transit ridership are better understood and models have been developed which can reasonably estimate the proportion of total trips between two geographical locations that will be made via mass transit. Both SCRTD and LARTS are presently using a model developed by Alan M. Voorhees and Associates for use in the Los Angeles area, a model which has been utilized in these analyses as well.

Basically, the Voorhees Model works as follows. First, a "marginal utility" function is calculated for a typical trip between the two subareas between which projections are being made. "Marginal utility" is defined essentially as a measure of the advantages of the private automobile over public transit; therefore, higher marginal utilities will result in lower levels of transit ridership and vice versa. Figure 7.2 shows the diversion curves developed empirically for the Los Angeles area, which specifically relate transit ridership to marginal utility. The second step in using the model is to use these diversion curves to predict the expected transit ridership for any calculated marginal utility. It is important to remember that the utility curves were derived empirically, and hence subject to uncertainties. It would be a mistake to view the model as an absolute predictor. Since the model has inherent uncertainties, any values calculated in this report have the same uncertainties plus the additional uncertainties associated with various assumptions made.

There are a number of variables which can be used to measure the relative advantage the private auto has over public transit. Voorhees related marginal utility to nine variables, which, essentially fall into two classes -- time and money.

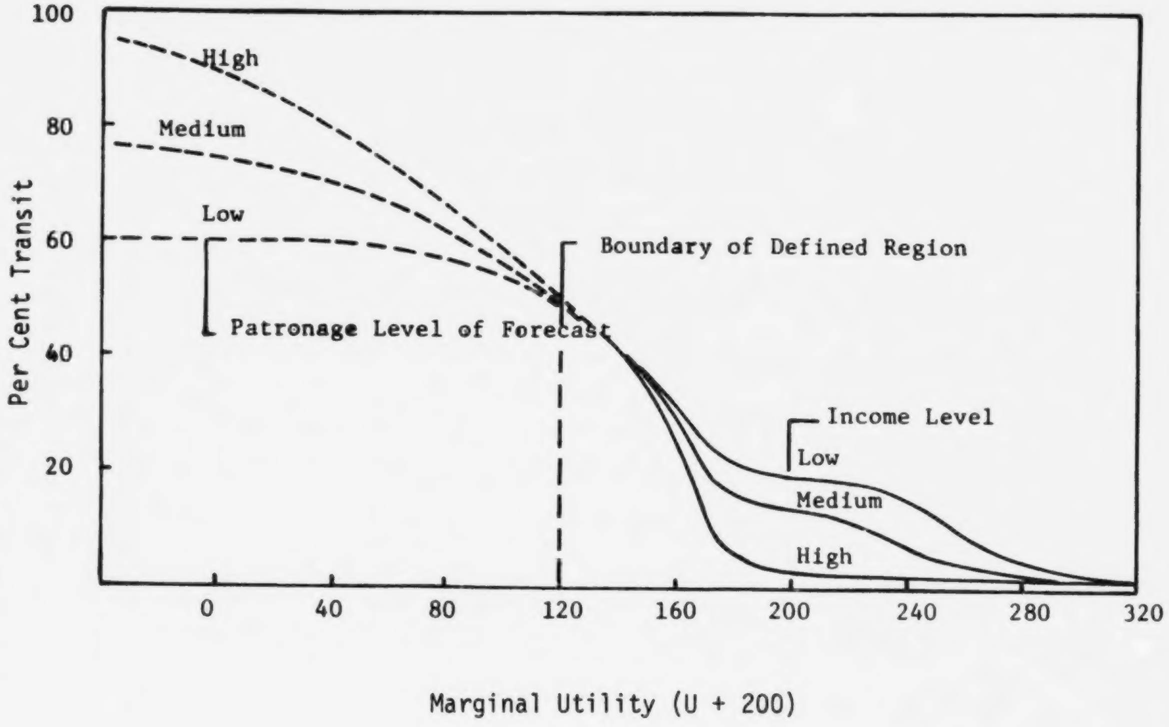


Figure 7.2 . Per Cent Transit vs. Marginal Utility

Source: Alan M. Voorhees and Associates, Inc., Los Angeles Mode Choice Model Development Study, February, 1972.

Within the group of nine variables used to formulate the marginal utility function (Equation 1), certain variables are more susceptible to change than others. Variables which are susceptible to change in the direction of decreasing marginal utility are the ones which hold most potential for decreasing VMT. Table 7.4 summarizes some implications associated with changing the marginal utility parameters.

$$\text{Marginal utility} = U = 2.5\,(Ta + Tw) + Tr - (2.5\,At + Ar) + \frac{F - (Ao + Ap)}{0.25I} \qquad (1)$$

where : Ta = transit access time in minutes (i.e. the time to walk to the bus stop)

Tw = transit wait time in minutes

Tr = transit riding time in minutes

At = automobile parking access time in minutes (i.e., the time necessary to find parking and walk to destination)

Ar = automobile riding time in minutes

F = transit fare in cents

Ao = automobile operating costs in cents (excluding depreciation and insurance)

Ap = automobile parking cost in cents (averaged over the round trip)

I = mean income of the home based zoned in cents per minute

Theoretically, some or all of the nine parameters can be modified in hopes of affecting increases in transit ridership. The effect of a program designed to alter these variables in various combinations will be examined in the next section.

Figure 7.2 illustrates that demand for public transit will increase if the marginal utility of the automobile is decreased. Transit ridership estimates for marginal utilities less than minus 80 are extrapolated. They reflect three levels of optimism for what transit ridership might become under rather ideal conditions. The Voorhees report recommends using the low patronage level of forecast in the Basin which implies the upper limit of transit demand is approximately a 60 per cent ridership(86).

TABLE 7.4

Control of Marginal Utility Parameters

Marginal Utility Parameter[a]	Potential for Control	Example(s) of Control Aimed at Decreasing Marginal Utility
Ta	Low	More bus stops and/or routes
Tw	Medium	Improved frequency of service
Tr	Medium	Exclusive busways for freeway lanes
At	Low	Peripheral parking, auto free zones
Ar	High	Ramp metering
F	High	Lowered fares
Ao	High	Gasoline tax, "smog" tax, tolls
Ap	Medium	Increased parking costs
I	Very low	Lower personal income levels

a - see Equation 1

Within the 'defined region', the Voorhees curves are drawn for three different levels of income. Various income groups will exhibit different responses to, or perceive differing marginal utility changes to a uniform change in actual conditions. Essentially, this results from the differing values placed on time and money within each economic class. Low income drivers will probably divert to public transit more rapidly than middle income drivers in the event a substantially increased cost penalty is associated with driving. However, since more low income people ride on transit now, the percentage increase in transit ridership within each income level could be about the same.

Percentage of daily VMT stratified by income group can only be inferred from relative trip generation rates, as average trip lengths have not been stratified by income categories. Average trip performance is generally reflected in the behavior of the middle income group and for purposes of these analyses, the mode split curves corresponding to this group have been used to characterize areawide average response to changes in marginal utility of the auto versus transit. Appendix H presents an illustration of the expected changes in transit ridership for various parameters as a function of three income levels.

In order to predict the effect of various strategies on transit ridership, it is necessary to have information on the nine variables which influence marginal utility (Equation 1). Table 7.5 lists typical values assumed for each parameter needed to simulate current conditions experienced during a commute type trip. When these assumed values are input to the Voorhees Model, an eight percent transit ridership is predicted (which corresponds to the current commute transit ridership (Table 7.1).

In order to simplify the analysis, certain logical combinations of variables were grouped; this lowered the effective number of variables to consider in control strategies to six. The six variables which will be analyzed in depth are given in Table 7.6.

Using the assumed values listed in Table 7.5 and the six variables in Table 7.6, curves were generated for estimating the percent transit ridership as a function of each of the six variables (Figures 7.3-7.8). Marginal utility was determined by holding five of the variables constant as the sixth was allowed to change.

TABLE 7.5

ASSUMED VALUES OF MARGINAL UTILITY PARAMETERS FOR A TYPICAL COMMUTE TRIP

Variable	Assumed Value	Source
Trip Length	10.5 miles	Table 5.4
Ta	5 minutes	Generally accepted value
Tw	7 minutes	15 minute headway, no transfer
Tr	48 minutes	LARTS, 1971 Travel Time Study
F	38 cents	30¢ basic fare + 8¢ for one additional zone
Ao	50 cents	4.8¢ per mile - assumed by Voorhees
Ap	2.5 cents	90¢ per day for estimated 5.8 percent who pay See Table 7.7.
I	8.3 cents/minute	$10,000 per year
At	2 minutes	A. M. Voorhees & Associates
Ar	23 minutes	Table 5.4

TABLE 7.6

MARGINAL UTILITY PARAMETER COMBINATIONS

Marginal Utility Variables	Symbol	Potential for Control	Relative Effectiveness
Transit fare (one way)	F	High	Low
Transit access and waiting time	T_a+T_w	Medium	Medium
Transit riding time	T_r	Medium	High
Auto operating and parking cost (one way)	A_o+A_p	Medium	High
Auto riding time	A_r	Medium	Low
Auto terminal time	A_t	Low	Low

NOTE: Income is considered a constant throughout, primarily because it is virtually impossible to control.

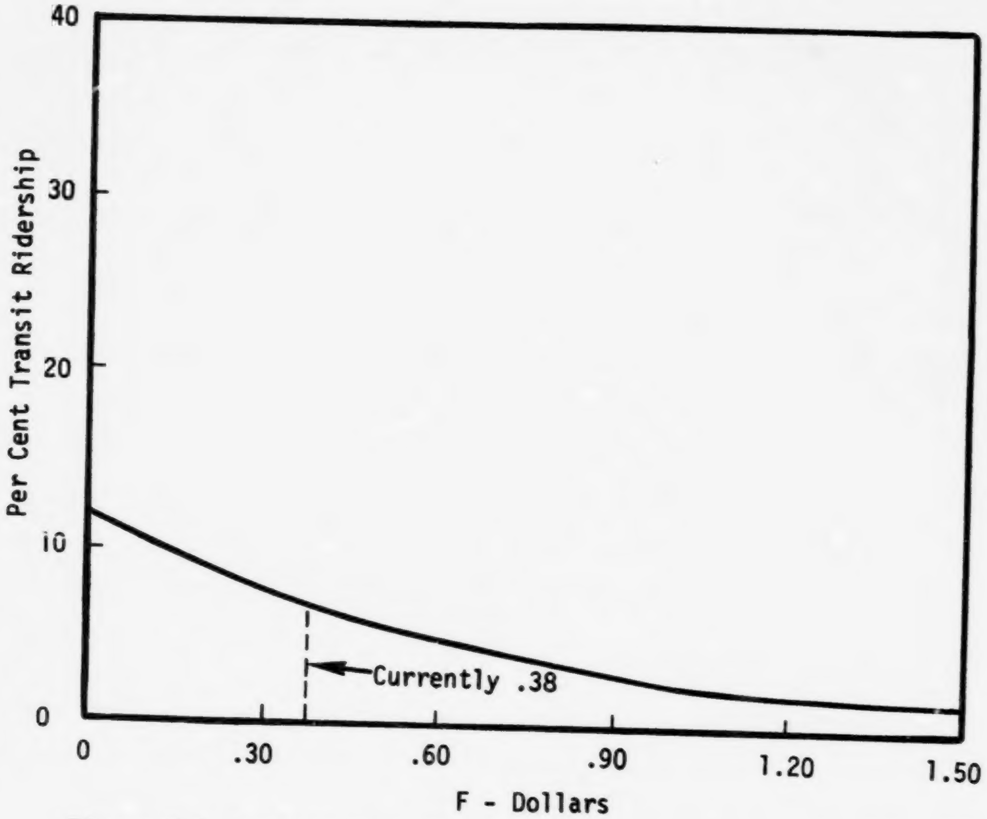


Figure 7.3. Transit Fare (One Way) vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

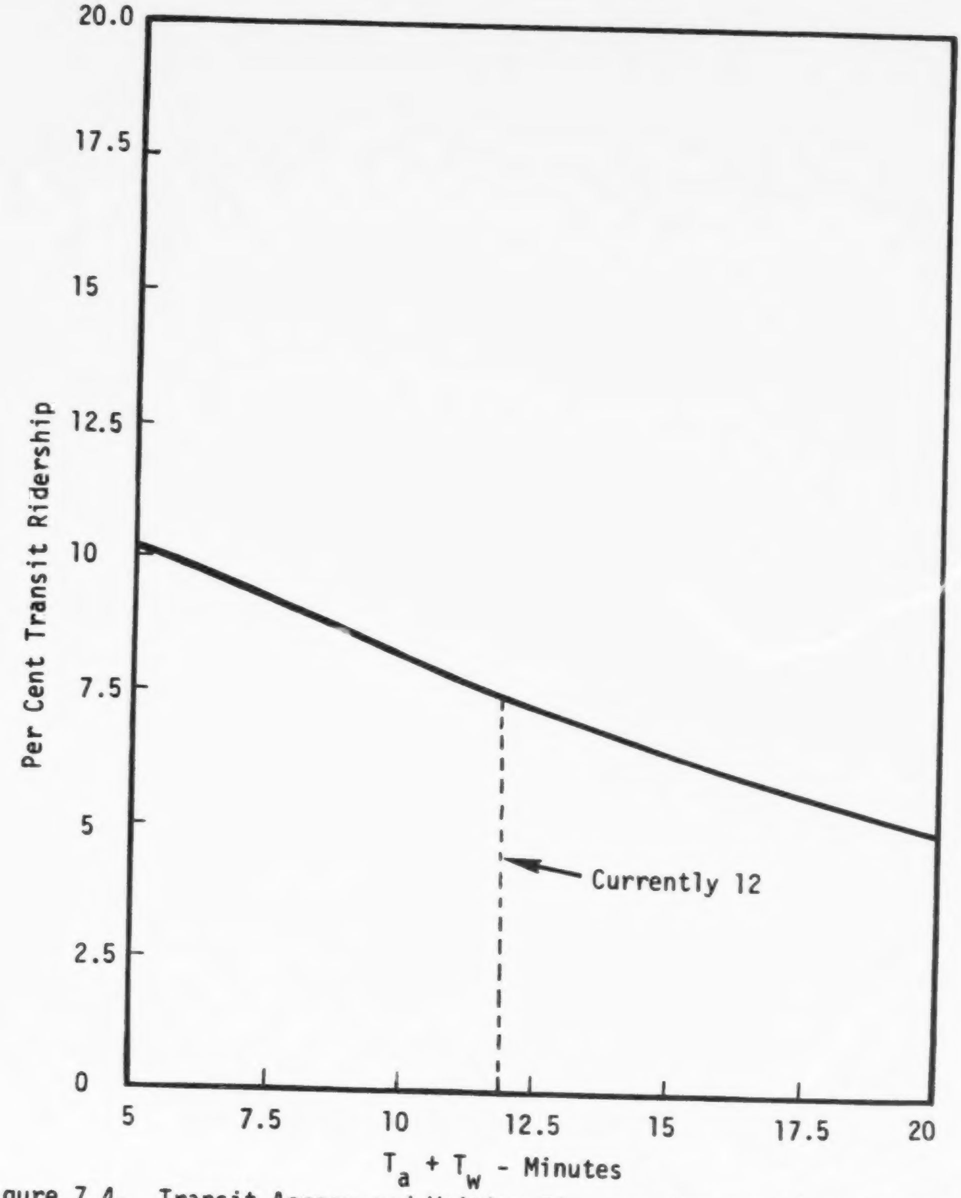


Figure 7.4. Transit Access and Waiting Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

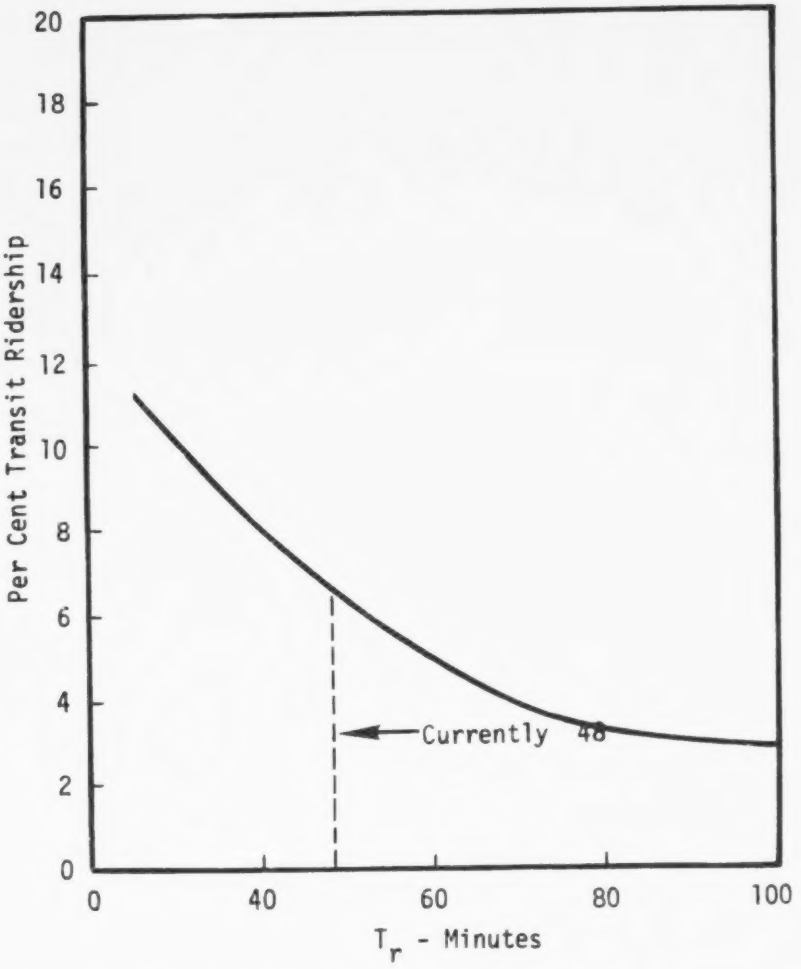


Figure 7.5. Transit Riding Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

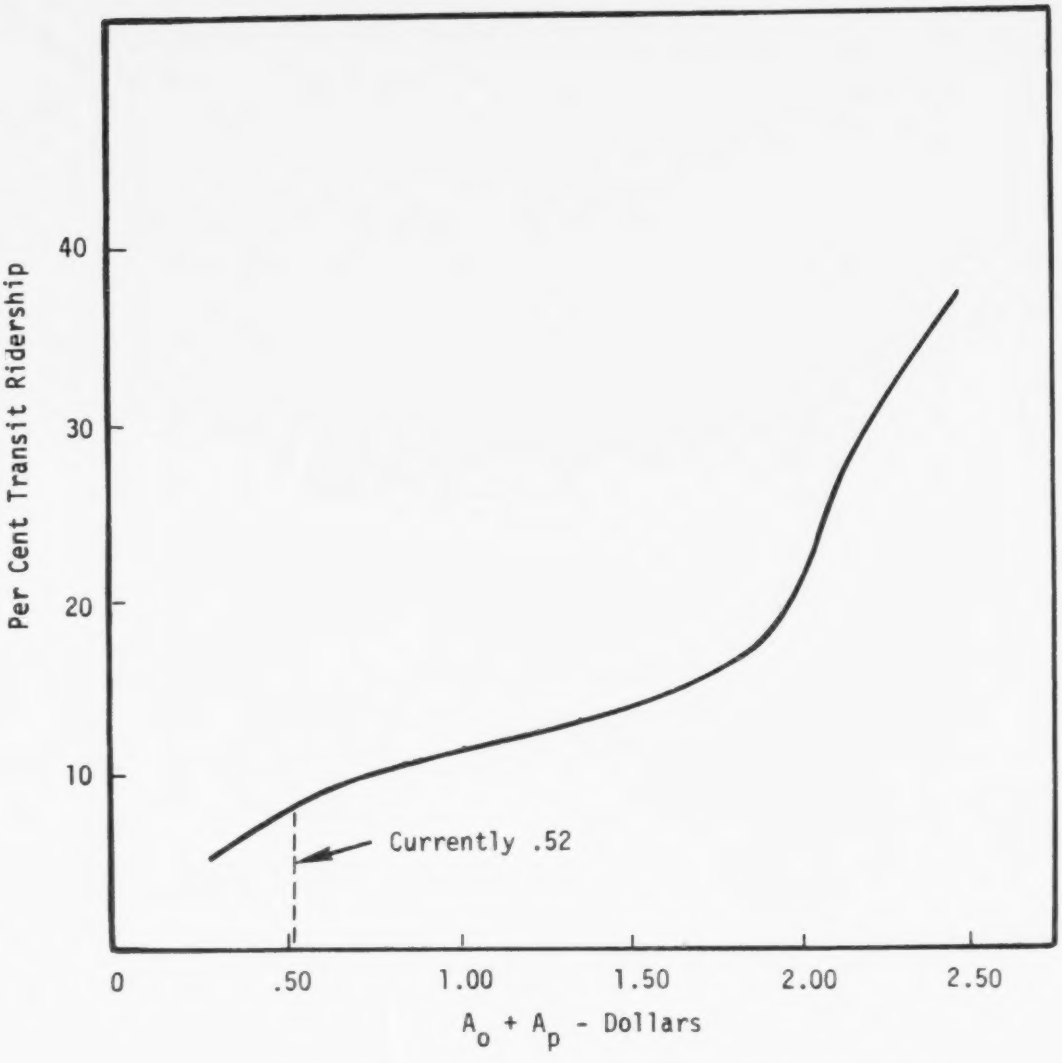


Figure 7.6. Automobile Operating and Parking Cost (One Way) vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

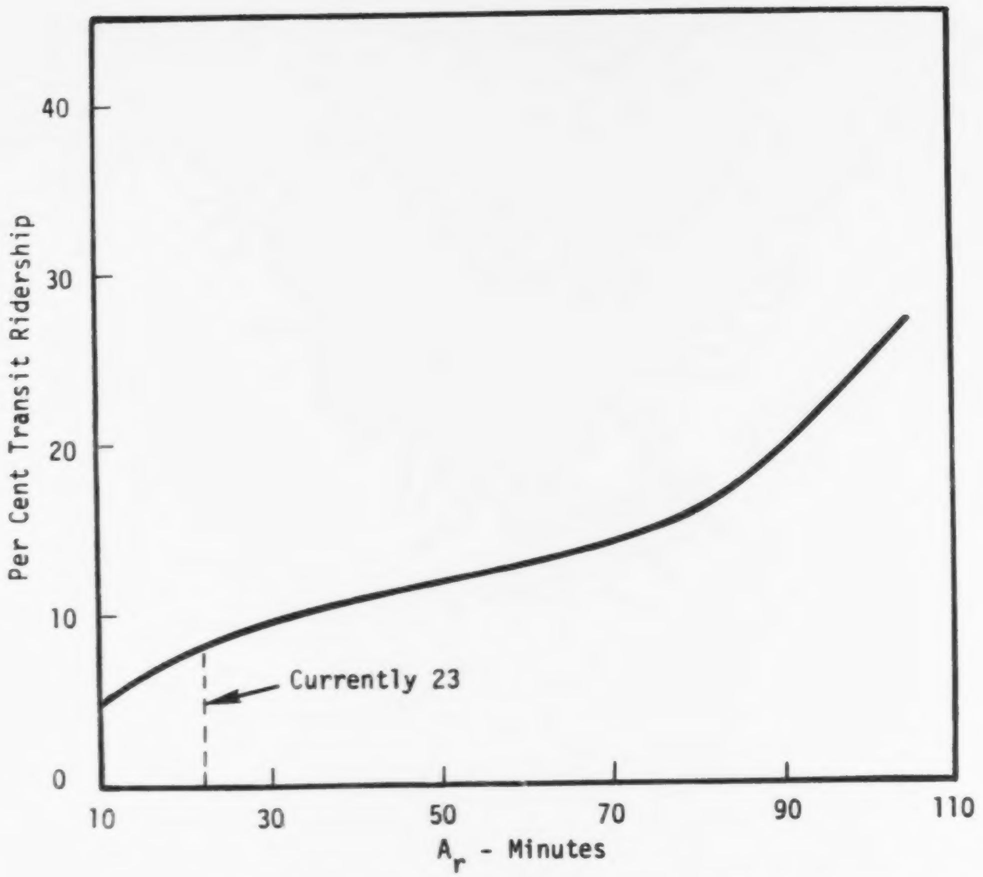


Figure 7.7. Automobile Riding Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

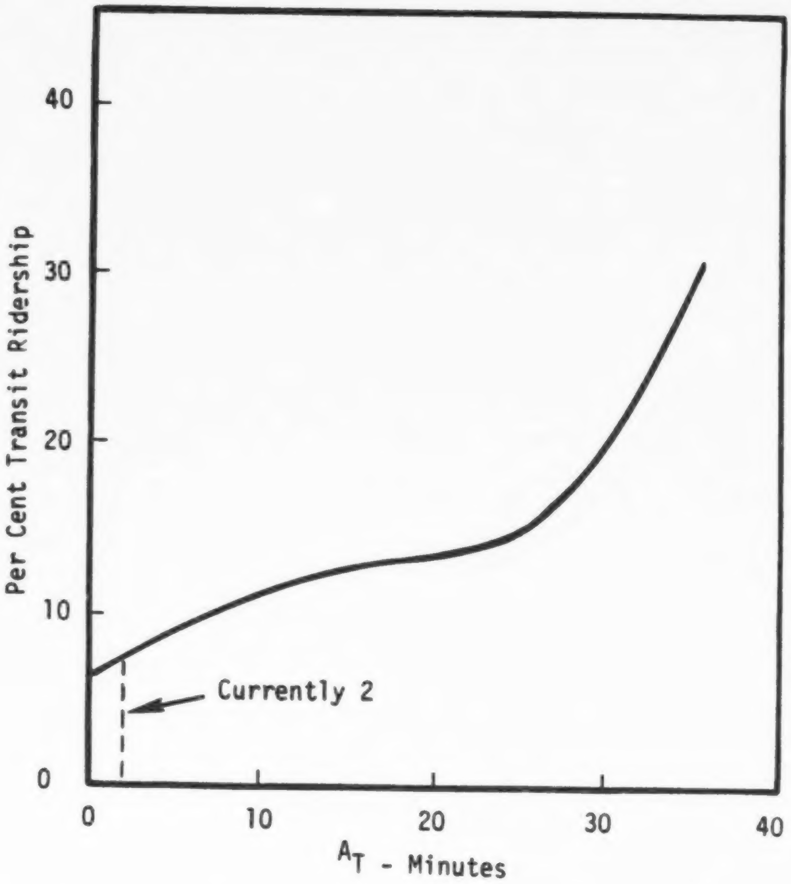


Figure 7.8. Automobile Terminal Parking Time vs. Per Cent Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model.

Figures 7.3-7.5 all relate to changes affecting transit variables. No penalities on use of the private auto are assumed. Figures 7.6-7.8 show the effect of penalizing the automobile while not attempting to improve public transit. In general, the latter approach is more effective in increasing the transit ridership. This implies strategies directed at controlling automobile usage will result in a higher VMT reduction than strategies aimed solely at improving mass transit.

An examination of the transit oriented variables shows them all being relatively inelastic with regards to increased transit ridership. This implies that making bus service more frequent, quicker, and cheaper will not induce much more additional patronage.

The most effective parameter, transit ride time, can only attract 15 per cent ridership under the most optimistic improvement. A free transit would probably attract less than 10 percent ridership. If one compares the two variables, time turns out to be more important than money. This turned out to be a fairly consistent finding -- the private auto user was more affected by inconvenience and time loss than by monetary considerations.

7.3 The Impact of Improved Public Transit

Using very optimistic assumptions which would make transit service free and as fast as the private auto, one might be able to achieve an overall 10 per cent VMT reduction (Appendix E, Sample Calculation #6a). However, by making more reasonable assumptions for an improved bus system which could be developed, one achieves only a 3 per cent VMT reduction overall in the Basin (Appendix E, Sample Calculation #6b).

7.4 The Impact of Incentives to Discourage Auto Use

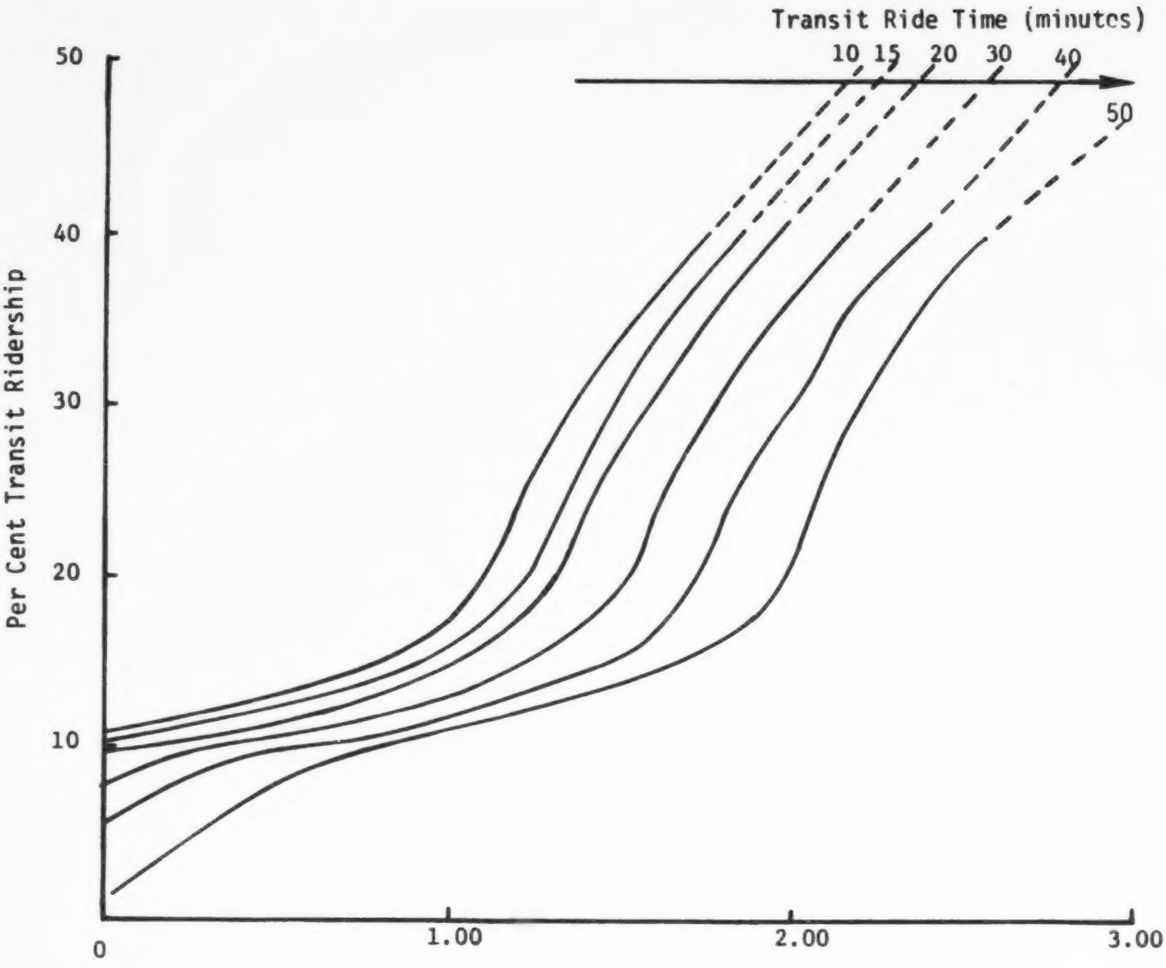
In comparison to transit variables, controls aimed at penalizing the automobile, are more effective. Theoretically, if the penalty placed on the auto is severe enough, high transit ridership and therefore, large VMT reductions can be achieved. The measures necessary to achieve large VMT reductions have to be very drastic though.

The problem with severe economic penalties for private auto use is they become very inequitable affecting the lower income classes the most.

For example, assuming no transit operation improvement, the combined vehicle operating and parking cost would have to be raised to approximately $4.00 per day ($2.00 per trip), an increase of 14 cents per mile in order to get to the saddle-point of the curve that separates the flat portion from the steeper, more responsive section (Figure 7.6). Similarly, if varied alone, the automobile travel time would have to be lengthened to more than 80 minutes (an average speed of approximately eight miles per hour) or the parking terminal time lengthened to 30 minutes to reach the same saddle point (Present commute time is 23 minutes).

7.5 The Impact of Improved Transit Service and Incentives to Discourage Auto Use

Figure 7.9 shows the demand elasticity for public transit in terms of improvements in transit riding time and increasing auto operating and parking costs. From the previous analysis these two parameters appeared to be the most elastic of the transit improvement and automobile deterrent measures respectively; yet, when they are applied as a pair fairly substantial actions must still be made in both to reach the most elastic portions of the curve. For example, if the transit riding time was made comparable to the automobile riding time, 23 minutes, and an additional



Auto Operating & Parking Costs (Dollars) Per Trip

Figure 7.9. Effect of Automobile Operating Cost, Parking Cost, and Transit Riding Time on Transit Ridership.

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

tax on either parking and/or travel of approximately 75 cents per trip (to make the combined costs equal to $1.25 per trip) would be necessary to reach the elastic portion of the curve.

This part of the curve occurs at roughly 20 per cent transit demands. If a 20 per cent ridership were achievable during the commute periods, one would only get a 4 per cent VMT reduction in the Basin.

It is important to note that the curves in Figures 7.3 to 7.9 are drawn for a typical commute trip. It is expected that the demand elasticities for non-commute trips will be even flatter necessitating even more stringent controls to achieve the same levels of riderships.

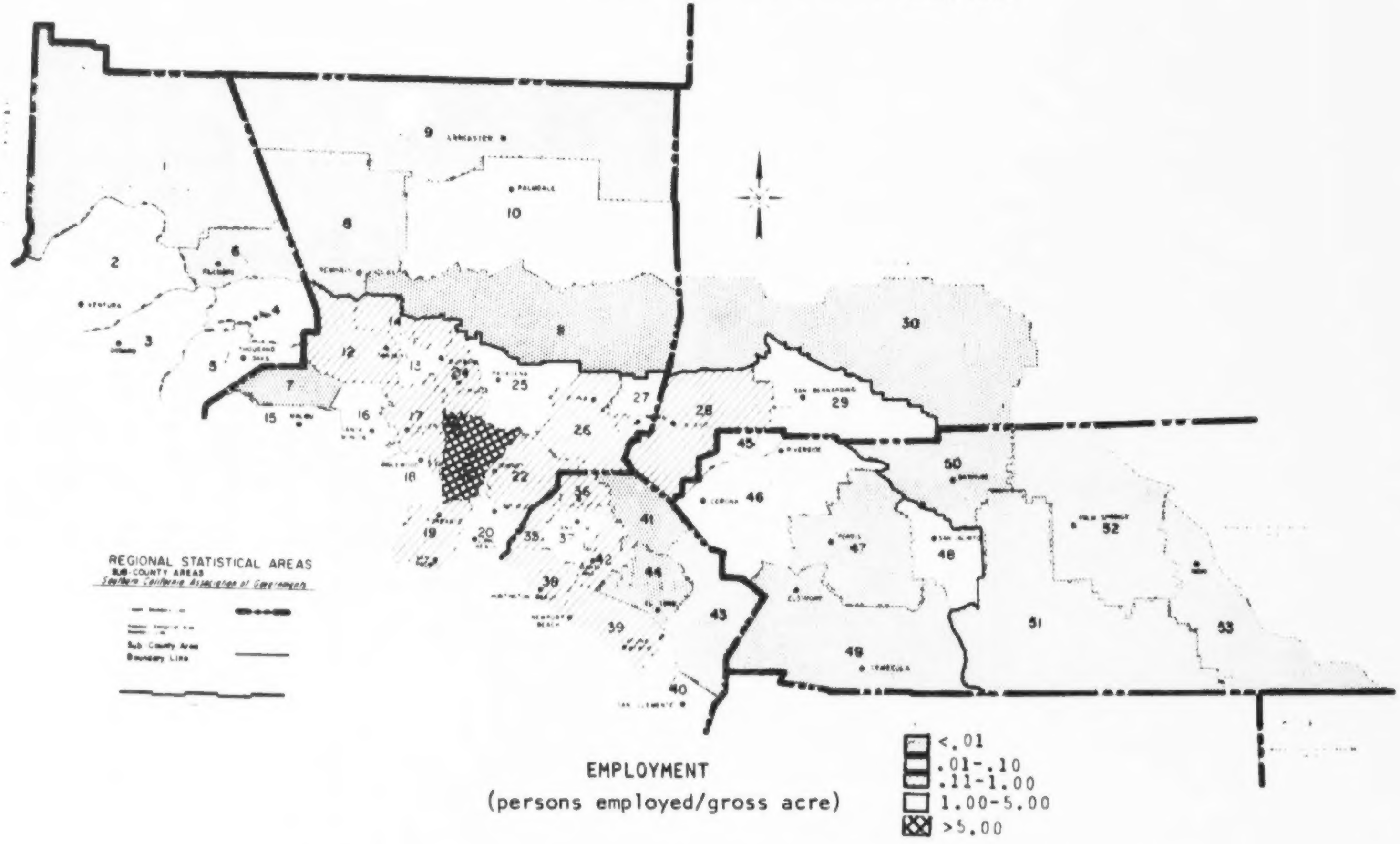
7.6 The Impact of Auto Free Zones

Prohibiting the use of automobiles in certain areas of the city could produce some reduction in daily VMT. Emissions from automobiles traveling within the area would be eliminated, and additional reductions would result from a diversion to mass transit by those who may find peripheral parking too inconvenient. These might be counterweighed to some extent by VMT increases due to thru traffic being diverted around the vehicle free zone.

This strategy must be applied to extremely dense activity centers to achieve significant reductions. The character of land use in the Los Angeles Basin is such that few such activity concentrations are identifiable. Figures 5.1 and 5.2 for example, illustrate the relatively uniform distribution of travel over the Basin and Figure 7.10 shows locations and densities of employment centers in the Basin.

The biggest employment center is the Los Angeles downtown control Business District (CBD), which is bounded by four freeways which serve both CBD-bound traffic and bypassing traffic. If the CBD were established

Figure 7.10. 1970 Employment in the LARTS Study Area



REGIONAL STATISTICAL AREAS
SUB-COUNTY AREAS
Southern California Association of Governments
Sub County Area Boundary Line
1
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LANCASTER
PALMDALE
VENTURA
THOUSAND OAKS
SAN BERNARDINO
RIVERSIDE
CORONA
PERRIS
ELSINORE
TEMECULA
SAN JACINTO
PALM SPRINGS
NEWPORT BEACH
SAN CLEMENTE
MALIBU
EMPLOYMENT
(persons employed/gross acre)
<.01
.01-.10
.11-1.00
1.00-5.00
>5.00

Source: Southern California Association of Governments, Employment Projections.

as a vehicle free zone, no increase in vehicle miles associated with through traffic would be expected because freeway access to the CBD could be controlled and VMT reductions associated with CBD-bound traffic would range from 104,000 to 1,027,000 vehicle miles depending upon what diversion to alternative modes of travel can be expected. (See Appendix E, Sample Calculation #7).

The most optimistic figure of 1,027,000 vehicle miles reduced represents less than 1 percent of the daily Basin total of 168,000,000 vehicle miles. In fact, over 30 centers comparable to the Los Angeles Downtown CBD would have to be pinpointed and closed off to achieve a 20 per cent reduction in vehicle miles in the Basin. The likelihood of ever achieving a sizeable VMT reduction through the creation of auto free zones is small. The land areas which would be affected must become quite substantial in order to get a significant travel reduction. In addition, most of the present land use patterns, especially with respect to parking, need to be changed before this strategy could even be seriously considered.

7.7 The Impact of Increased Parking Costs

Table 7.7 presents data on the type of parking associated with the work trip. Overall, more than 91 per cent of the commuters use free parking facilities of one kind or another. This value varies as a function of geographical area; workers driving into the CBD were more likely to pay for parking. In fact, only 46 per cent of those driving into the CBD were able to park in free lots. In general, land use practices which have established and encouraged automobile use through provisions for free parking, make increased parking costs a relatively poor control strategy. Essentially, very low VMT reductions could be expected because:

TABLE 7.7

TYPE OF PARKING - FIRST TRIP TO WORK
(Average Weekday)

Type of Parking	Number	Per Cent
Lot free	1,720,000	82.6
Street free	177,200	8.6
Garage free	12,800	0.6
Lot paid	107,000	5.1
Garage paid	15,200	0.7
Street meter	4,900	0.2
Resident property	27,800	1.3
Not parked	15,400	0.7
Service or repairs	1,600	0.1
Total	2,082,500	100.0

Source: LARTS 1967 Origin-Destination Survey, December, 1971

1) parking costs (from Figure 7.6) are relatively inelastic until very high charges are made
2) too many parking lots are currently free and in private ownership making it difficult to institute a massive pricing policy which would be uniformly equitable and yet effective enough to cover a large number of lots
3) raising the price of parking in congested areas such as the CBD affects only a small segment of the population and if the penalties are severe enough, they tend to be discriminatory
4) a massive program would have to be undertaken to substantially increase the percentage of drivers now paying for parking -- approximately six per cent of the commuters.

7.8 The Impact of the Four Day Work Week

As shown in Table 5.4, approximately 32 per cent of total vehicle miles in the South Coast Basin are attributable to commuting trips between work and home. A large proportion of workers in the Los Angeles area typically commute to work five days a week on the conventional 40 hour week schedule.

For certain types of jobs, a shift to a 4 day - 40 hour week would be feasible, thus resulting in the elimination of one round trip to work per week for each employee affected. However, comparison of total average Saturday to average weekday traffic volumes indicates that increased recreational and other travel is likely to cancel the VMT reductions due to reduced work trip requirements. Studies documenting current daily travel patterns in the Los Angeles area indicate, as illustrated in Table 7.8, that if 70 per cent of the 1980 work force, as determined by the Southern California Association of Government (SCAG)(66), switched

Table 7.8

Trip Frequency by Trip Type and Day of Week

Day	Home to Work	Home to Other	Home to Shop	Work to Other	Other to Other	Work to Shop	Totals
Monday trips	212	89	147	58	132	61	
vehicle miles	2226	605	441	394	897	464	5027
Tuesday trips	195	124	125	81	125	84	
vehicle miles	2047	843	375	551	850	638	5304
Wednesday trips	214	90	117	99	123	69	
vehicle miles	2247	612	351	673	836	524	5243
Thursday trips	198	131	97	68	138	70	
vehicle miles	2079	891	291	462	938	532	5193
Friday trips	218	99	133	93	164	79	
vehicle miles	2289	673	399	632	1115	600	5708
Saturday trips	35	178	235	8	238	8	
vehicle miles	3367	1210	705	54	1618	61	4015
Sunday trips	20	200	145	5	177	1	
vehicle miles	210	1360	435	34	1204	8	3251
						Total	33,741

*Note: trip frequencies are averages from a population of 199 survey cars

Source: Kearin, D. H. and R. L. Lamoureux, A Survey of Average Driving Patterns in the Los Angeles Urban Area, Systems Development Corporation, Santa Monica, California, February 28, 1969 to a four day work week less than a one percent reduction in total daily vehicle miles would occur (Appendix E, Sample Calculation #8).

7.9 The Impact of Increased Car Pool

The current level of car pooling in the Basin is also very low. In a recent survey taken in the greater Los Angeles area (Appendix F), only 4.3 per cent of the persons polled indicated that they travel to work in a car pool. An indicator of car pooling activity is the automobile occupancy rate, which is computed as the average number of persons carried per automobile. Table 7.9 presents current average occupancy rates for various categories of trips in the South Coast Basin. Note that the work related trips have the lowest occupancy rates. A closer examination of the work trips made on the freeway shows greater than ninety per cent of the drivers commuting alone (Figure 7.11).

Table 7.9

Current Automobile Occupancy Rates in the South Coast Basin

Average	Home Other	Other-Other	Work-Other	Home-Work	Home-Shop	Total
Weekend Day	2.0	1.6	1.1	1.1	1.5	1.8
Weekday	1.7	1.3	1.1	1.1	1.4	1.4

Source: LARTS-1967 Origin Destination Survey, December, 1971, p. 71

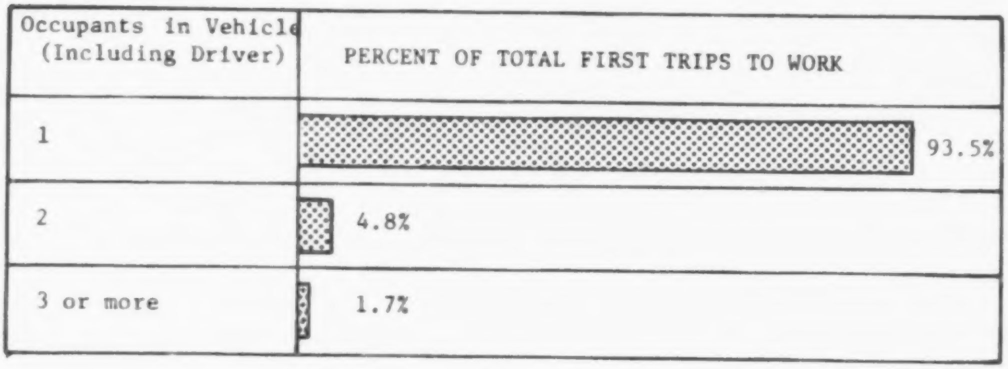


Figure 7.11. Distribution of Weekday Driver Trips to Work Via Freeway by Number in Vehicles

Source: LARTS - 1967 Origin-Destination Study, December, 1971, p. 71

Since the auto occupancy rate is so low, significant VMT reductions can be achieved through increased car pool activity. Figure 7.2 presents curves indicating the total Basinwide VMT reductions associated with increased automobile occupancy. Derivation of these curves is explained in Appendix E, Sample Calculation #2. Table 7.10 lists occupancy rates corresponding to a few specified VMT reduction goals.

Mandatory carpooling on freeways during peak traffic periods has been proposed as a control measure. However, even if all freeway commute travel was in carpools, a 20 per cent VMT reduction could not be achieved. Commute travel by freeway users accounts for less than 25 per cent of total daily VMT (including both freeway and non-freeway travel segments (43)). If all such commuters were in car pools of 3 and no additional VMT were generated by car pool assembly and dispersal, the maximum VMT reduction possible would be 17 per cent.

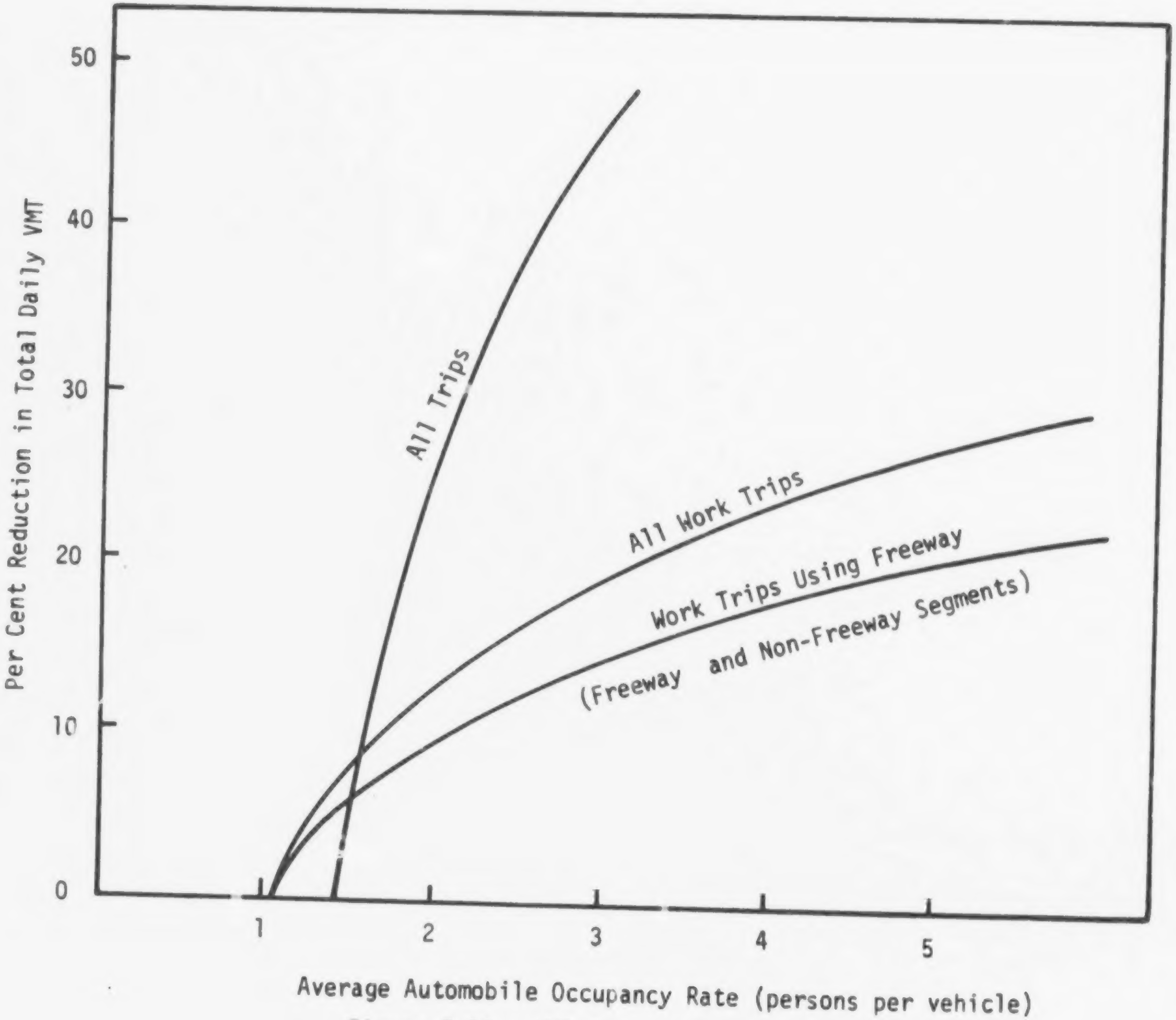


Figure 7.12. VMT Reduction vs. Automobile Occupancy.

Table 7.10

Average Automobile Occupancies Required to Obtain Various VMT Reductions

Overall Auto Occupancy	Commuting Auto Occupancy	Freeway Commuting Auto Occupancy	% Reduction in Total VMT
1.4 (current)	1.1 (current)	1.1 (current)	0
1.7	1.7	2.1	10
1.9	3.2	---	20
2.2	6.2	---	30
2.6	---	---	40

Assumptions:

1) No change in transit ridership

2) No change in trip demand

7.10 The Impact of Exclusive Bus and Carpool Lanes on the Freeway

Reserving freeway lanes for high occupancy vehicles has been facilitated through Assembly Bill No. 1, which was enacted into California Law in November 1970. Use of this law in the South Coast Basin could potentially affect a VMT reduction via increased transit ridership and carpooling activity.

As shown in Figures 7.5 and 7.9, giving mass transit a travel time advantage will result in increased transit ridership; this has already been observed on the Shirley Highway in Virginia (54). Similar results can be expected of carpools.

Reserving a lane on freeways during peak travel times presumably would have a two fold effect. The reserved lane would be free of congestion and any congestion already existent on the freeway would be aggravated with the removal of capacity.

It is difficult to estimate the magnitude of the VMT reduction potential of this program because other alternatives are open to automobile drivers. In addition to increased transit ridership, it is possible and probable that further voluntary staggering of commuter times and shifts of travel from the freeways onto surface streets might result. Hence, to maximize the impact of exclusive carpool and bus lanes, the alternatives should be made less attractive.

Levels of carpooling are limited by difficulties in arranging the carpools which, in turn, are the result of the diverse travel patterns in the Basin. In a survey conducted on Los Angeles residents, over three-fifths of the commuters said it would be "extremely difficult" or "very difficult" to arrange a car pool if they had to (see Appendix F). This might be alleviated by establishing carpool pickup points near on-ramps to the freeways. To get carpoolers to the pickup point, a local public transit feeder system could be utilized. Since the maximum potential for this strategy exists in the low density residential suburbs, the feeder system should probably be comprised of dial-a-ride buses, subscription buses, and jitneys (presently illegal in Los Angeles).

Another alternative would be park-and-ride facilities similar to the one proposed for the Santa Ana Freeway. This would allow transit riders or carpoolers an opportunity to quickly make the parking lot-to-home trip or home-to-parking lot trips on a flexible time schedule.

The VMT reduction potential of park-and-ride facilities is not as great as that of public transit feeders because of the VMT by individuals getting to the parking lot,and because of a resistance to leave the automobile once inside it. Kiss-and-ride activity would be similar in terms of the VMT reduction. Nevertheless, where public feeders cannot be provided, park-and-ride facilities should be provided.

Exclusive lanes for carpools and buses presumably only affect the commuter travel on freeways. During the off-peak hours, the travel time advantage of such a program could not be maintained easily and therefore would be virtually ineffective for additional VMT reductions.

Commuters who normally do not use the freeways have many options in terms of alternate routes. These drivers will be untouched by a control program geared to the freeway system.

In Appendix E, Sample Calculation #9, the impact of an exclusive bus-carpool lane on the freeway is estimated. Initially, the potential diversion of auto-person trips to mass transit was estimated for a hypothetical busway system on the freeways with extensive park-and-ride facilities. Hence, vehicle mileage reductions are not expected from the drive to the freeway.

By generously assuming that a 20 minute travel time advantage over automobile travel could be maintained by the transit vehicles, a 15 percent ridership could be assumed yielding a 2.5 percent reduction in the Basin-wide daily VMT.

In the Caltech Environmental Quality Laboratory Plan (see Section 3.2), a graduated "emissions" tax was proposed which peaked at 2.25 cents per mile for pre-1965 cars. In comparison, the estimated average current cost of gasoline in the Basin is approximately three cents per mile of travel (46). Hence, in response to the Caltech proposal and to simulate the effect of doubling the price of gasoline, a further analysis was performed with a three cents per mile increase in the automobile operating cost. The estimated effect is a potential further reduction of 0.7 percent; hence, the effect of passenger diversions onto freeway buses when a three cents per mile tax is applied to automobiles is a 3.2 percent reduction in daily VMT.

As stated previously, little is known about the factors which affect the level of carpooling between two geographic locations. It is expected that a carpool lane, which would give carpool automobiles travel time advantages over other automobiles on the freeway would be a strong incentive for carpooling, but it cannot presently be stated how effective such an incentive will be in raising the level of carpooling.

Numerous organizations have pointed to the goal of achieving an average vehicle occupancy of 1.5 persons per vehicle on the Los Angeles freeway system during the commute hours. One report claimed that this goal could be attained by 1975 through incentives for carpooling (3). In response to this it will be assumed that the level of carpooling in the proposed bus-carpool lane is enough to attain this goal. Appendix E, Sample Calculation #9 shows that if 24 percent of the freeway traffic, or 38 percent of the people using the freeway switched to three-man carpools. The goal can be achieved and the resultant VMT reduction would be approximately 4.4 percent of the daily Basin-wide VMT.

An additional complication in the analysis is the possibility that a portion of the potential new transit riders, estimated in the initial part of the analysis, may elect to form a carpool instead of taking a bus. Consequently, VMT reductions estimated by an independent determination of new carpooling activity might affect the VMT reductions attributable to new transit ridership. It would be extremely optimistic to simply add the two affects to estimate the total reduction because of this overlap. The combined VMT reduction potential of this program is probably no more than five to six percent of the total daily VMT.

Analysis of Results for Incentive Type VMT Reduction Strategies

It appears from the previous analyses that incentive type measures are not very effective at significantly reducing VMT. No strategy or combination of strategies was able to even approach the 20 percent VMT reduction goal of the Air Resources Board. In fact, it does not seem possible to achieve even a 10 percent VMT reduction by 1977. A realistic goal for the South Coast Air Basin using these measures would be to reduce VMT 5-8 percent by the year 1977. To achieve even this goal will require a considerable effort -- public transit will have to be substantially improved and concurrently, private automobile use will have to be explicitly discouraged through either time or monetary penalties.

The fundamental reason for why every strategy examined gave such insignificant results goes back to Figure 7.2. Very simply, the marginal utility of the automobile is not easily changed. Using the Voorhee's model, developed from present perceptions of public transit in Los Angeles, one faces a near impossible task of diverting auto commuters into public transit. Every "reasonable" incentive type strategy ended in only a small decrease in marginal utility. Consequently, significantly higher transit riderships can only be hoped for if a change in the marginal utility curves occurs. This implies greatly improving the transit service relative to the automobile so that the public's perception and attitudes towards public transit become more favorable. Herein lies the dilemma many transit authorities face; namely, how to improve service at higher operating costs and attract enough ridership to pay for the additional expenses. Recently, in an attempt to save money and cut costs, many transit authorities have been doing the opposite. Service has been lowered in the hope that the money saved from the austerity programs was more than the revenues lost from decreased ridership. This is usually done on the theory that most of the present ridership consists of "captive riders" with no alternative mode of travel, e.g. the young, old, and poor.

The question than becomes how can a public transit authority justify improving its level of service without the guarantee of additional ridership or conversely, how can the individual commuters be expected to divert to a public transit system it feels is grossly inferior to the private automobile? The answer, if there is one, seems to be a simultaneous attempt must be made to make the transit service more attractive in itself and to provide strong disincentives to private use of the auto.

In light of the slow nature of change, improving transit service initially will probably result in lowered profits. Therefore, the transit system may have to be subsidized. Eventually it is hoped, the penalties on auto use will be effective enough to move the commuters into improved transit service. It is only after this that the shape of the marginal utility curves may have to be reevaluated. When they become more favorable for transit ridership, the chance for obtaining a significant VMT reduction from incentive measures will be at hand. Table 7.11 summarizes the impacts of the strategies discussed in this section.

Table 7.11. Summary of Impacts for Various Control Strategies

Strategy Description	Approximate % VMT Reduction
Much Improved Public Transit	$\simeq 3$
Improved Transit and Tax on Auto Use	$\simeq 4$
Auto Free Zone (e.g., L.A. C.B.D.)	$\simeq 0.6$
Increased Parking Costs	Negligible
Four Day Work Week	$\simeq 0.6$
Exclusive Bus and Carpool Lane	$\simeq 2.5$
Exclusive Bus and Carpool Land with 3¢/mile tax	$\simeq 3.2$
Increased Commuter Carpools to Achieve an Average Automobile Occupancy of 1.5 on Freeways	$\simeq 4.4$

8.0 REGULATORY PROGRAMS

The previous chapters have examined a variety of incentive type measures (the "carrot" approach) to reduce VMT in the Basin. The measures were basically ineffective at achieving significant VMT reductions. This chapter explores a set of direct regulatory controls (the "stick" approach). As a rule, it is generally easier to estimate the impact of direct controls. This is not always the case, however, as will be shown for the case of limiting auto registrations.

Direct regulatory controls are authoritarian in nature and characterized by an agency essentially establishing a mandatory policy, rule, or regulation to be followed. To be effective, the penalties for violating the policy or regulation must be set high enough to discourage any violation. One such program is gas rationing where a large fine is placed for any violations of the administrative rules established to run the program. Those regulated by the program have few decisions to make: they are simply told to abide by the "rules of the game."

Indirect regulatory controls leave more room for individual decision making; consequently, it is less authoritarian, and in general, less predictable. An example of this type of control would be an "emissions tax," as proposed by the EQL team and others (29, 34, 46). The individual under this control decides for himself whether he should reduce his driving in order to save money or whether he should continue driving and pay the tax. In addition to being more difficult to assess, indirect controls usually take longer to assess. For example, pricing schemes typically show both short term and long term demand elasticities. In other words, in the case of an "emissions tax," it is very likely the first year many motorists will simply pay the tax and continue driving; in the second year, some motorists will reconsider the savings possible from driving less and may join a carpool or ride the bus to work.

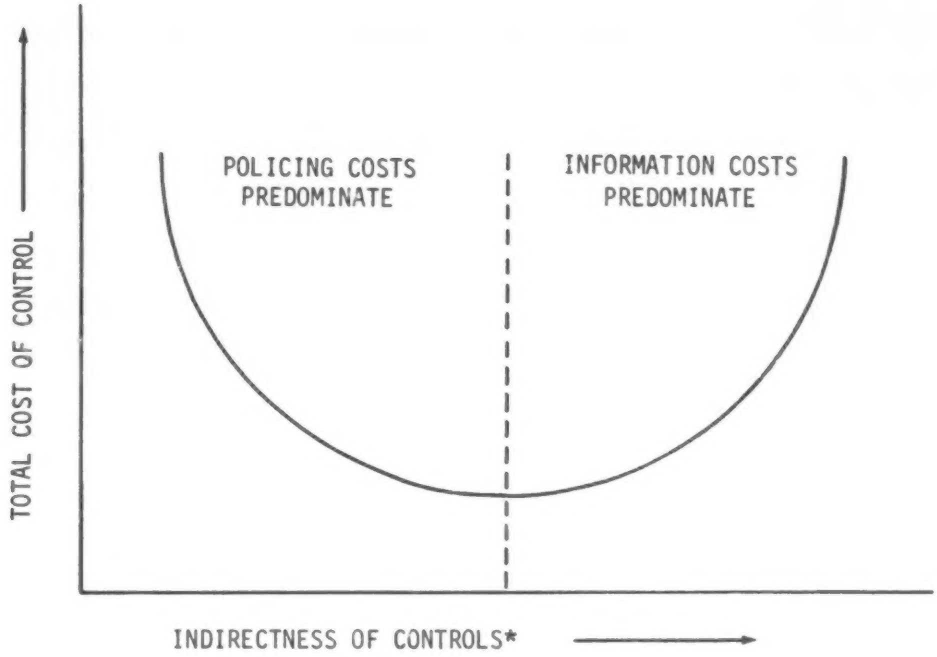
The costs associated with either direct or indirect controls can be equally high as shown in Figure 8.1. In general, "the more indirect the control, the greater will be information costs for it to be satisfactorily implemented or even compared with other controls in terms of efficiency ... enforcement and monitoring costs for rigid direct controls may be exceedingly high. If the perceived level of control is overly oppressive to the individual or organization being regulated, non-legal or questionably moral devices or political pressure may be attempted to thwart or neutralize the impact of the control (28)."

8.1 Limitation of Second, Third, ... Car Ownership

Analysis of the survey presented in Appendix F of this report indicates that the vehicle mileage attributable to family cars designated by respondents as car #2, #3, #4, etc., account for nearly 42 percent of total annual vehicle mileage (see Sample Calculation #10 in Appendix E). Conceivably a program which restricts the use of second and third family cars might result in significant reductions in VMT.

Quantification of the impact of such a program is very difficult for several reasons. It is not presently known how many trips by these "extra" cars are unnecessary. One would expect that the necessary trips would be shifted to the principal family car but vehicle mile reductions would result from the elimination of some unnecessary trips and the shift of some trips to alternate modes of travel. Estimating the increase in travel via the primary family car is difficult. In addition, it is not presently

Figure 8.1. Relative Costs for Varying Degrees of Controls


POLICING COSTS PREDOMINATE
INFORMATION COSTS PREDOMINATE
TOTAL COST OF CONTROL
INDIRECTNESS OF CONTROLS*

*Different controls are assumed along the horizontal axis with the most direct to the left and the most indirect to the right

Source: D'Arge, R.C., "Economic Policies, Environmental Problems, and Land Use: A Discussion of Some Issues and Strategies in Research," presented at NSF Conference on Research Needs in Planning our Physical Environment, Boulder, Colorado July 25- Aug. 5, 1972.

known how many of the designated second or third cars are indeed subsidiary in importance to the primary car (e.g., husband and wife must both work, but in opposite directions from home, therefore, both need a car). Many of the above uncertainties are a function of the availability of alternative modes of transportation.

Presumably, implementation of a program restricting multiple-car ownership would be accomplished through the present vehicle registration program. For example, a graduated registration fee increasing with the number of family vehicles registered might be implemented. However, it appears that many options would be open to circumvent such a restriction. Automobiles cannot be attributable to a family by surname because presently a housewife, for example, may use her maiden name in registering a car. Similarly, the address of the owner cannot be used as the business address of the owner may be substituted on the registration. Unrelated roommates with the same surname would also be unduly penalized by such a system. Consequently, restrictions placed specifically on second or third cars will be difficult to implement under current registration procedures. A restriction on all cars would be easier to implement and would lower second or third car usage indirectly.

8.2 Limitation of Auto Registrations

Figure 2.10 shows the growth in automobile registrations in the Basin. A program which would slow down this growth might result in significant automobile emission reductions. Each car that is brought into the Basin will be adding to the total vehicle miles driven and if an older car could be exported, a corresponding drop in vehicle miles might be expected. Since emissions from older cars are generally greater than those from newer cars, a resultant drop in emissions would occur.

The effect of such a program cannot be quantified principally because of the following. Although it can be assumed that there is a basic average level of travel, experience has shown that newer cars are utilized more. Thus, there would probably be a tradeoff -- as the vehicle population becomes newer, while being held at essentially a constant level, the average number of miles traveled per car may go up.

Reaching a zero growth level in itself would be difficult in the short run because it would be difficult to control the registration of vehicles brought into the area by new residents. As long as the relevant planning organizations do nothing to discourage growth in the Basinwide population, one should expect these new residents to come. Although the population growth is slowing down, a net emigration from the Basin cannot be expected by 1977.

The only other source of control would be on the purchase of new autos. One could conceive of a program which required the exportation or junking of a car before a new car could be purchased. Trading of cars presently in the Basin would be exempt, but before a dealer could sell a car that was previously not registered in the Basin he would be required to demolish or export a car that was registered.

There are several possible implications of such a program. For example, the used car supply in the Basin would probably go down. The emissions impact would be positive, but as with most pricing schemes there is the risk of undue discrimination against the financially disadvantaged people of the Basin, who would find it increasingly difficult to own cars.

In addition, such a measure could create an artificial market for junkers to be exported, resulting in higher prices for new autos. Initially, one might expect a reduction in second car ownerships as the "extra" family cars were exported, but after that supply has been diminished, it is possible that families will keep their primary cars longer. Before such a program is implemented, a closer look should be made of the microeconomic implications. Possibly some governmental subsidy would be required to accelerate the shift to a newer vehicle population, in which case, it is not at all clear the benefits would exceed the costs.

8.3 Limitation of Gasoline Consumed (Gas Rationing)

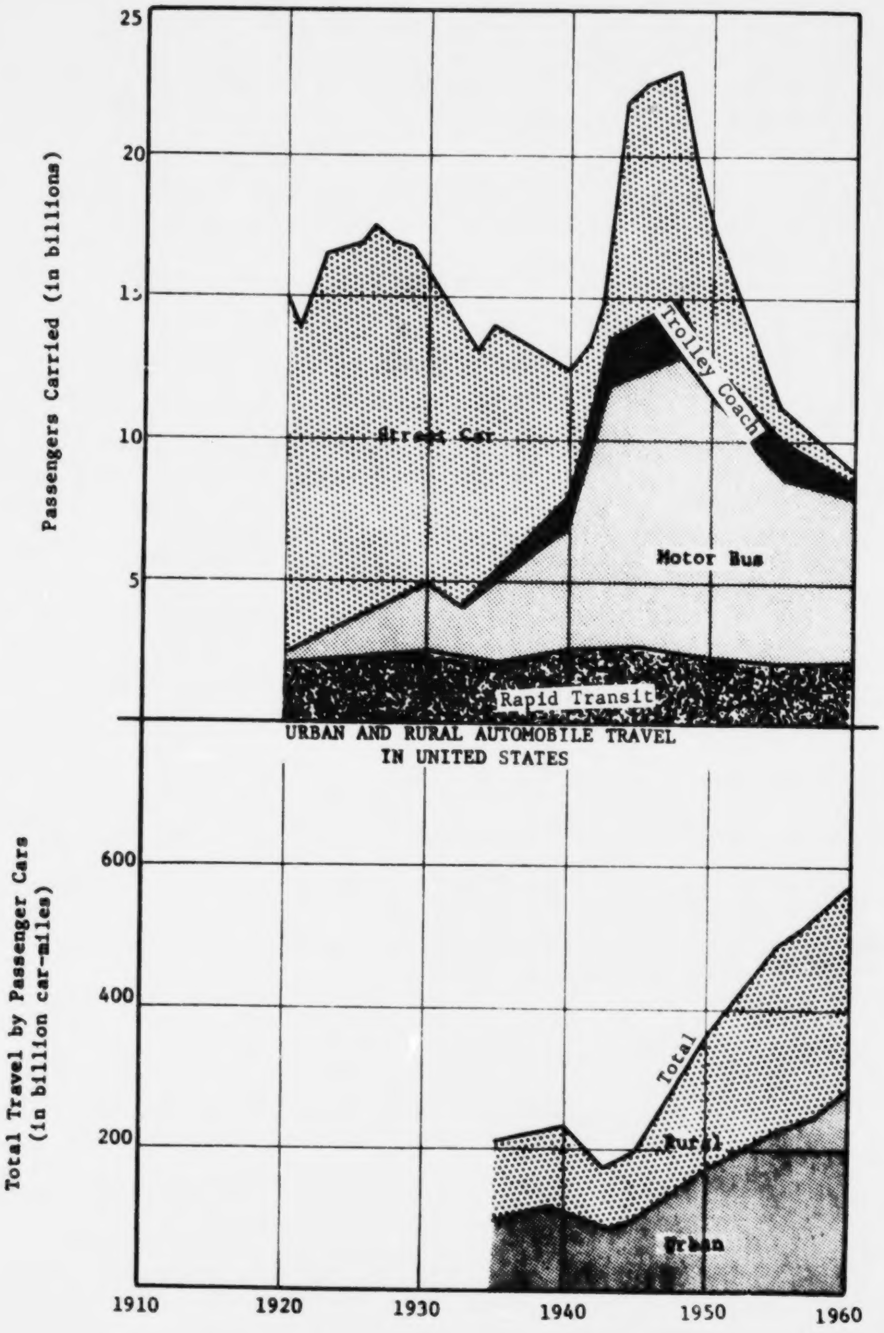
Since air pollution is most directly related to the consumption of gasoline, an obvious control strategy is to restrict or regulate its use. Gasoline rationing was implemented during World War II as a conservation measure (see Appendix I for history of gasoline rationing during the War). Many who were involved in the program viewed it as a necessary evil, and although the rationing system had many shortcomings, it was effective in conserving gasoline and significantly reducing VMT. As seen in Figure 8.2, it was also a very effective measure in increasing transit patronage. Gas rationing during the war, although a severe measure, appears to be the only measure implemented during the last 50 years which has been able to effect reduced auto use and induce increased transit ridership.

In view of the massive pollutant reductions required to achieve the air quality standards, it appears that rationing gasoline is the only alternative which would accomplish the task. Such a program has serious implications for the present life styles of the Basin's residents and needs a more detailed evaluation before it can be advocated.

As a control strategy, gasoline rationing does have some features which make it attractive:

- Interim control strategy — of the measures considered, it has a relatively high adaptability for use as a seasonal control strategy.

Figure 8.2. Trends in Public Transit Patronage in the United States



Source: Haase, R. H., Are We Willing to Pay for Congestion-Free Transportation?, Rand Corporation, P-2813, January, 1964.

- Not irreversible — properly designed and administered, rationing could be very flexible; unlike strategies such as retrofit devices, this control can be easily and quickly lifted.
- Mid-course corrections possible — the degree of control necessary can be changed easily to adjust for changing conditions and circumstances.
- Not technology dependent — does not rely on non-existent or unproven technology (e.g., catalytic converters).
- Cost effective — the consumer is inconvenienced but should save money.
- Induces other programs effectively, e.g., car pooling and increased public transit.
- Conservation oriented — aimed at prevention rather than cure; fuel economy likely to be increased rather than decreased (e.g., some retrofit devices).
- Precedent and experience available — the program has been instituted before; hopefully, the pitfalls of the World War II experience can be anticipated and minimized.
- Relatively rapid response — the time lag for experiencing air quality improvements is less than most programs, e.g., pricing schemes.

Despite the features of a gas rationing program as a control strategy, there are at least an equal number of real obstacles and problems which can be anticipated should any attempts be made to implement and enforce such a program. It is these issues which must be adequately addressed and studied before a gas rationing program can be recommended. Among the difficulties to be encountered are:

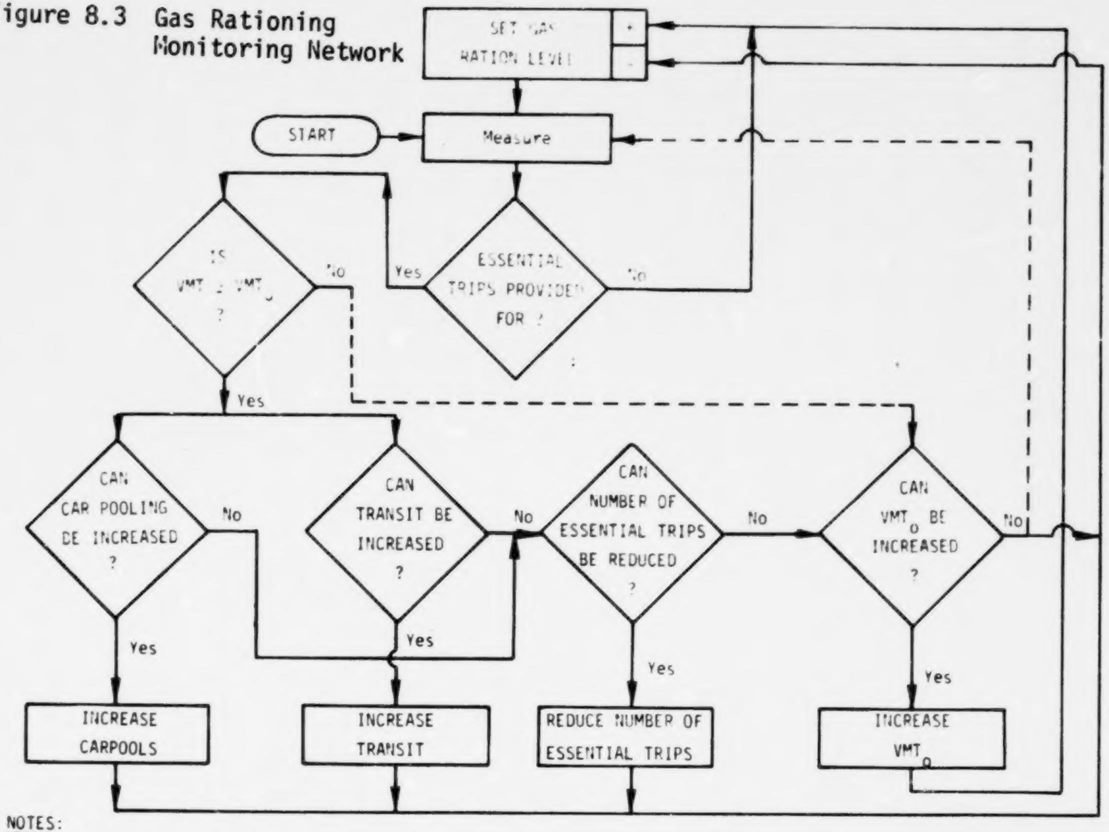
- Administrative problems — the World War II program appears to have encountered significiant administrative problems.
- Institutional constraints — it is unlikely many institutions will support a massive rationing program.
- Enforcement problems — black markets, bootlegging and counterfeiting of coupons were all widespread practices during the War; these problems would probably pose even more of a problem today.

- Micro-economic implications — any massive rationing program will significantly affect the economy of the region affected; these effects are difficult to assess accurately but they would be major.
- Lack of alternative modes of travel — it has yet to be determined how much additional travel can be handled either by the present transit system or by a projected increase in levels of transit service.
- Public acceptability — it is doubtful much public support could be mustered for a gasoline rationing program.
- Legal status — it is unclear if the legal authority to implement such a program exists.

If the implementation obstacles for establishing a gasoline rationing program can be dealt with adequately, Figure 8.3 illustrates schematically how such a program could be monitored. The key questions which must be addressed are presented in the diamonds; responses and program monitoring elements are given in the rectangles. Actually, any interim VMT reduction strategy could be set up to be monitored in this fashion since the same questions have to be answered.

The chart in Figure 8.3 shows an ongoing feedback and control network. To start the program a target VMT must be specified lower than the present VMT and which would result in a significant air quality improvement. The goal is to iterate through the cycle several times until a VMT_0 can be reached which will allow attainment of the standard and yet provide for all essential travel through provisions for increased carpooling, transit services, etc. The goal of attaining VMT_0 must be superseded, however, by the qualification that there is a minimum level of travel below which the economy and normal functions of the Los Angeles region cannot function, i.e., the program should proceed only as close to the goal as possible without killing Los Angeles.

Figure 8.3 Gas Rationing Monitoring Network


SET GAS RATION LEVEL
+
-
START
Measure
ESSENTIAL TRIPS PROVIDED FOR ?
Yes
No
IS VMT ≥ VMT$_0$?
No
Yes
CAN CAR POOLING BE INCREASED ?
No
Yes
INCREASE CARPOOLS
CAN TRANSIT BE INCREASED ?
No
Yes
INCREASE TRANSIT
CAN NUMBER OF ESSENTIAL TRIPS BE REDUCED ?
No
Yes
REDUCE NUMBER OF ESSENTIAL TRIPS
CAN VMT$_0$ BE INCREASED ?
No
Yes
INCREASE VMT$_0$

NOTES:

1) VMT$_0$ is level of VMT to meet standard
2) Measure means measure VMT, Auto occupancy, Transit Ridership, Essential Trips, etc.
3) --- is an optional path.
4) ⊕ means make gas rationing less stringent
5) ⊖ means make gas rationing more stringent

The target VMT_0 can be modified at any time to take account of technological breakthroughs, changing vehicle age distributions, new land use patterns, or simply a change in the rigidity of the air quality standard. Conceivably, the program could be ongoing, running through two six month cycles per year -- the summer VMT_0 would be more stringent than the winter VMT_0, due to the seasonal nature of the oxidant problem. During the winter cycle, the previous summer results could be evaluated and decisions made for the appropriate VMT goal for the forthcoming summer season.

The optional path drawn on the diagram is to constantly look for a chance to relieve the system of the gas rationing element. The program places a priority on trying to achieve higher transit and carpooling levels before attempting to dictate the number of trips allowed and leaves as a last resort a relaxation of the standard. On the other hand, it recognizes that it takes a finite lead time to implement an increase in transit ridership.

Indirect controls such as pricing schemes could be monitored in the same manner. In this case, one would simply replace the gas rationing level with an "emissions tax" or "smog tax." These controls have several disadvantages although they are probably much more acceptable to the public. First, the length of a typical cycle would be longer because of short term and long term demand elasticities. This also makes it much more difficult to monitor. To fully assess the potential impact of a pricing scheme would probably require at least two years, i.e., to complete one iteration or cycle. Also, after the completion of a cycle, it is difficult to accurately determine the appropriate level of control necessary for a desired change because the responses to indirect controls are likely to be non-linear.

In other words, doubling the tax is not likely to result in twice the VMT reduction experienced from the first tax. The response from direct controls tends to be much more linear and therefore, more predictable.

9.0 SUPPLY OF ALTERNATIVE MODES OF TRANSPORATION

It must be assumed that there is a level of trip making in the South Coast Basin which is viewed by the residents as necessary for economic and social well being. Governmental jurisdictions (Federal, State, County, local) have enabled this mobility by funding, constructing, and maintaining facilities for personal transportation and through the provision of public transit either directly or through franchised, possibly subsidized, operations. This minimum level of mobility is not well defined through present data sources; to date the objective in transportation planning has been to satisfy travel demand and maximize mobility. Only recently has the need for some limitation on mobility in the larger urban areas been recognized. The ramp metering project conducted by the California Division of Highways, which was described previously, is a prime example of current techniques which involve restriction of certain individuals' mobility.

Various strategies discussed in this report attempt to affect automobile emissions reductions through reductions in vehicle miles of travel which would result in one of the following: diversion of trips from automobile trips to other modes of travel (bus, car pool, bicycle, walking, new "pollution-free" vehicle) or an elimination of the trip. If the alternative modes of transportation are deficient in supply, it is possible that the level of trip making will reach the previously mentioned minimum point before the desired VMT reduction can be realized. Further VMT reductions will only be possible if increased capabilities for alternative modes of travel are provided. Hence, it is clear that the minimum trip making level must be defined.

It is also necessary to know what the supply or potential supply of alternative modes of transportation are before embarking on any large-scale VMT reduction program. Table 9.1 presents the current supply of buses in the South Coast Basin. It is estimated that on short notice the current bus supply could be raised to approximately 2000 buses (see Sample Calculation #11 in Appendix E); however, many more buses will be necessary to meet the increased demands for transit that will result from the proposed VMT reductions.

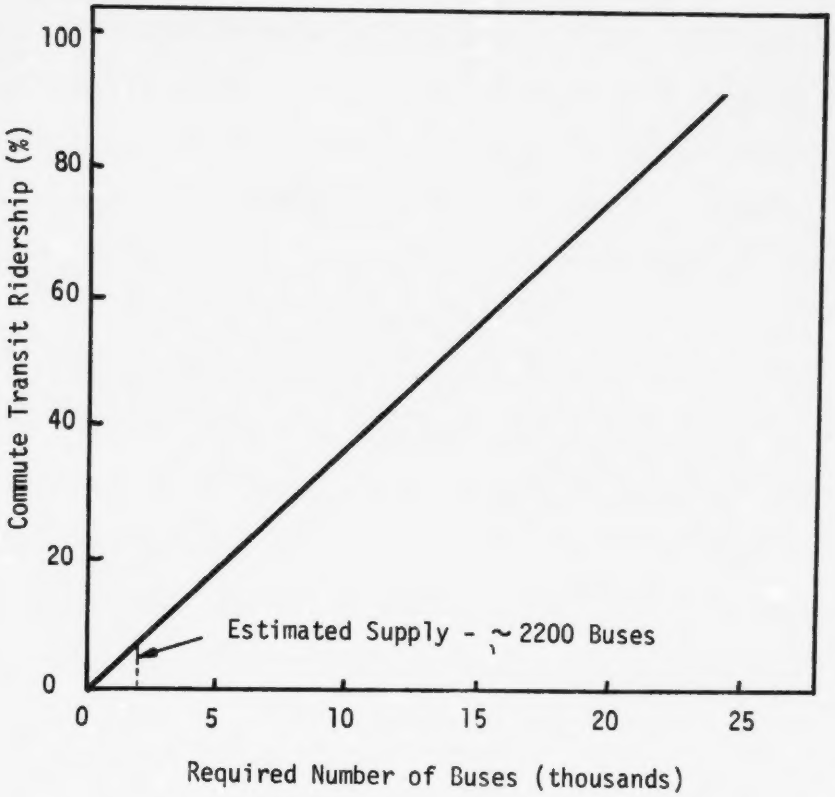
Table 9.1. Current Supply of Buses in South Coast Basin

Transit Organization	Number of Buses
SCRTD	1511
Orange County Transit District	9[a]
Long Beach Municipal	123
Santa Monica Municipal	105
Montebello Municipal	19
Torrance Municipal	50
Culver City Municipal	21
Total	1838

[a] OCTD will have 250 buses by 1975

SOURCE: From most recent financial statements of each organization.

Based on meeting the commute period travel demands the required bus supply was calculated in Sample Calculation #11 (Appendix E) for various levels of commute transit riderships. The results are displayed pictorially in Figure 9.1. To achieve a 20 per cent transit ridership during commute times, approximately 5000 buses or 3000 more than the estimated supply will be required, resulting in a 4 per cent total VMT reduction (plus any ridership changes that could be achieved during off peak hours).



Assumptions:

1) 1977 trip distribution
2) Average occupancy of 40 persons per bus
3) Each bus makes three round trips during each commute period

Figure 9.1 Bus Requirements for Commute Transit Riderships

The present cost of conventional urban buses is on order of $40,000 per bus. If 3000 more buses were required, as discussed in the previous example, a capital outlay of $120 million would be required for bus purchases alone, not to mention requirements for the hiring of new employees, planning, etc. It should be recognized that fixed costs (capital costs, etc.) normally account for only about 20 to 30 per cent of the cost of providing conventional transit services. In comparison, SCRTD's initial estimates for the cost of a fixed rail rapid transit system was $1.2 billion in 1968.

Through present sources of funds (see Appendix D) it will not be possible to make an acquisition of that large a fleet. SCRTD, for example in 1972, has been allotted only $43 million through the Mills-Alquist-Deddeh Act (SB 325) for transit planning and capital expenditures (89). Additional funds would have to be mandated through additional legislation.

Even if the financial obstacles could be overcome, the interim nature of vehicle restraints that might be implemented (i.e. until newer, more controlled vehicles dominate the auto population) requires that an important policy decision be made. Is such a large capital outlay justified if the new, forced demand for mass transit will only be temporary? In other words, are the short-range transportation goals and requirements of this program consistent with the long-range transportation needs of the Basin? It would seem reasonable to allow for the necessary lead time ation of the artificial transit demand created by vehicle use restraints. would retain a high level of attractiveness and utility, even after elmination of the artificial transit demand created by vehicle use restraints? This ultimately will be accomplished through better land use planning.

Social costs of air pollution are not well quanitified. A sounder, more balanced basis for analysis must be developed before the policy decisions and trade-offs outlined above can be properly evaluated and acted upon.

In addition to the financial implementation obstacles, the limiting factor for vast expansions to bus services is the present bus production capabilities of the United States. SCRTD personnel (89) indicated the two major companies producing conventional urban transit buses are operating essentially at capacity. Numerous other cities, in addition to Los Angeles, will be attempting to acquire large numbers of new buses on short delivery schedules as part of their programs to meet the 1977 air quality standards. The willingness and ability of the major bus producers and other manufacturers to gear up to meet such a high, short-term demand is uncertain as is the economic impact it would have on the price of buses.

Increases in transit capacities can be achieved by means other than the purchase of new buses. For example, the licensing of jitney operations, presently illegal in the Basin could help meet the new peak hour demands for transit. Taxi services could be subsidized during peak hours so that they could be used to feed and redistribute patrons of truckline routes (e.g. buses on exclusive freeway lanes). Additional incentives for carpooling could be implemented. Bicycling, which is a potentially viable mode of transportation in the Basin, could be encouraged through the careful addition of bicycle routes. The above schemes all merit further study; however, it is not expected that implementation of these programs could substantially reduce the bus fleet requirements.

10.0 PROPOSED CONTROL STRATEGY (SOUTH COAST AIR BASIN)

The relationship between air pollutant emissions and ambient air quality is still not well understood, despite major efforts to develop both sophisticated analytical and statistical models.(33,47,81,83) The inaccuracies in the ability to predict air quality result from many factors, some of which are:

- Inadequate and questionable emission inventories
- Questionable air quality data
- The representativeness of test cycles to actual driving patterns; e.g., 7-mode vs. CVS
- The uncertainties of the real effectiveness of various control strategies.

The control strategy recommendations presented are based on proportional rollback techniques that relate estimated emissions to air quality in a linear fashion. This has been done primarily because of the time constraints of the study. The validity of this technique is highly questionable and consequently does not serve as an adequate basis on which to implement severe control measures.

Full implementation of the control measures outlined should allow attainment of the air quality standards by the 1977 target date. Implementation of Phase I measures can be justified on the basis of air quality improvements at reasonable costs. The impact of implementing the Phase II control measures is staggering. This study had neither the time nor the data base to fully evaluate the social, political, and economic ramifications of such a measure. Hence, it cannot be recommended at this time although it would, in all probability, result in the desired goal.

The control measures outlined are not new and have been proposed elsewhere; no "magic solution" was found and only incremental improvements can be expected from each strategy. The primary reason for this is a host of control options were evaluated, the large majority of which proved to be relatively ineffective. The California Air Resources Board is actively engaged in field testing a variety of control strategies and has extensive experience in the field of air pollution control; it would be a mistake to usurp their efforts and knowledge with massive unproven control measures. The severity of the air pollution left few alternatives for measures which would be adequate to accomplish the program requirements.

Phase I Measures:

1. Evaporative Controls (See Section 4.2) — Accelerate the evaluation program of evaporative control devices for 1966-1969 vehicles. At the earliest date, if the devices are shown to be effective and available, a mandatory installation program should be implemented.

2. Oxidizing Catalytic Converters (See Section 4.2) — Accelerate the evaluation program of oxidizing catalytic converters. If these converters are effective and become available, incentives should be made to encourage their use on 1966-1974 vehicles.

3. Mandatory Inspection/Maintenance (See Section 4.1) — Implement a program of inspection and maintenance for in-use vehicles. The program recommended is the second stage expansion of the recommended program of the Governor's Task Force on Periodic Vehicle Inspection and Maintenance. This measure will provide significant reductions in motor vehicle emissions and is necessary to derive the full benefit from both

new and used car emission controls. This should result in a reduction of ten to twelve percent of the reactive hydrocarbons left uncontrolled in 1977 (approximately 40 tons/day).

4. Mandatory Conversion of Fleet Vehicles to Burn Gaseous Fuels (See Section 4.3) — Implement a program requiring the conversion of all fleet vehicles of model years 1970-1974 to use a gaseous fuel. This measure will significantly improve the emissions from vehicles which presently account for a disproportionate share of the miles travelled in the South Coast Air Basin. The reduction from this program is estimated to be approximately 12 tons/day of reactive hydrocarbons.

5. Evaporative Loss Controls (See Section 4.4) — Implement a program to substantially reduce hydrocarbon losses from fueling operations, specifically from the loading of underground storage tanks at the gasoline station and from the service pump to the automobile fuel tank. The control of these marketing losses is estimated to be approximately 65 tons/day of reactive hydrocarbons.

6. Additional Stationary Source Controls — Stationary source controls were not evaluated as part of this study; however, as mobile source controls become more effective, the proportionate contribution of stationary sources to the problem will increase. The emission reductions claimed from this strategy were calculated by the EPA and have tentatively been accepted. They are as follows: 6 tons/day from dry cleaning vapor control, 25 tons/day from degreaser substitution, and 45 tons/day from a 50 percent strengthening of the Los Angeles County Air Pollution Control District's Rule 66. All in all, approximately 76 tons/day of reactive hydrocarbons can be controlled from additional stationary source controls.

7. Mass Transit (See Chapters 7.0-9.0) — The level of mass transit available presently is totally inadequate to handle any substantial increases in ridership. Improving mass transit both in terms of frequency and efficiency of service and the breadth of coverage in areas served, is a necessary first step to attract additional riders. It is also needed for making any measures which discourage private auto use more effective. Finally, should Phase II be implemented, it is imperative as an alternative mode of travel. A much closer examination should be given to establishing express bus and carpool lanes on certain freeways. Park-and-ride facilities, as well as bicycling, should be encouraged in more areas of the Basin.

Implementation of a series of mass transit improvements plus a variety of incentives to discourage the private use of the automobile should result in a 5-8 percent reduction of VMT in 1977. The reduction in reactive hydrocarbons is estimated to be no more than 5 percent of the remaining controllable emissions or approximately 17 tons/day after the implementation of the Phase I measures.

Phase II Measure:

8. a) VMT Reduction (See Section 8.3) - Implement a massive program to significantly reduce the vehicle miles travelled within the Basin, hence eliminating the major source of hydrocarbon emissions. This can probably be done most effectively by rationing the gasoline supply. Rationing can be accomplished either by limiting the supply to the actual consumers from the gasoline station or from the refinery to the service station; or

b) Evaporative Retrofit Device and/or Oxidizing Catalytic Converters with VMT Reduction - If upon completion of the Air Resources Board's studies of these controls (Measures 1 and 2), it can be shown these devices can make a significant impact on the air quality improvement of the Basin, implement programs to require their installation. A detailed examination should be made of costs and benefits to be derived by a mandatory retrofit program. This will become more important as time passes and the older cars represent a smaller contribution to the overall problem.

Assuming a given reduction in VMT is the equivalent percent reduction in gasoline consumed, an 87 percent VMT reduction is required beyond the Phase I measures. This would result in approximately 292 tons/day of reactive hydrocarbons not being discharged into the atmosphere (283 tons/day from vehicular emissions and an additional 9 tons/day from marketing losses).

This same level of control could be accomplished by an 81 percent VMT reduction after implementing mandatory installation of the controls described in Measures 1 and 2(evaporative control devices and oxidizing catalytic converters). The approximate reductions in reactive hydrocarbons would then become: 26 tons/day from evaporative control devices; 84 tons/day from oxidizing catalytic converters; 8 tons/day from marketing losses; and 174 tons/day from an 81 percent VMT reduction after all other control measures had been implemented.

Figure 10.1 summarizes the impact of the strategies outlined and their contribution to arriving at the desired goal.

10.1 Implementation Obstacles

Implementation obstacles for the various control measures outlined generally fall into the several categories shown below. A brief evaluation of the probable obstacles likely to be encountered for each control measure is presented.

Technical Obstacles — Obstacles involving the design of hardware, details of administrative procedure, or specification of standards or acceptance limits necessary for implementing recommended control measures.

Legislative Obstacles — Obstacles involving the writing and passing of laws, rules, and regulations required for instituting and administering control measures.

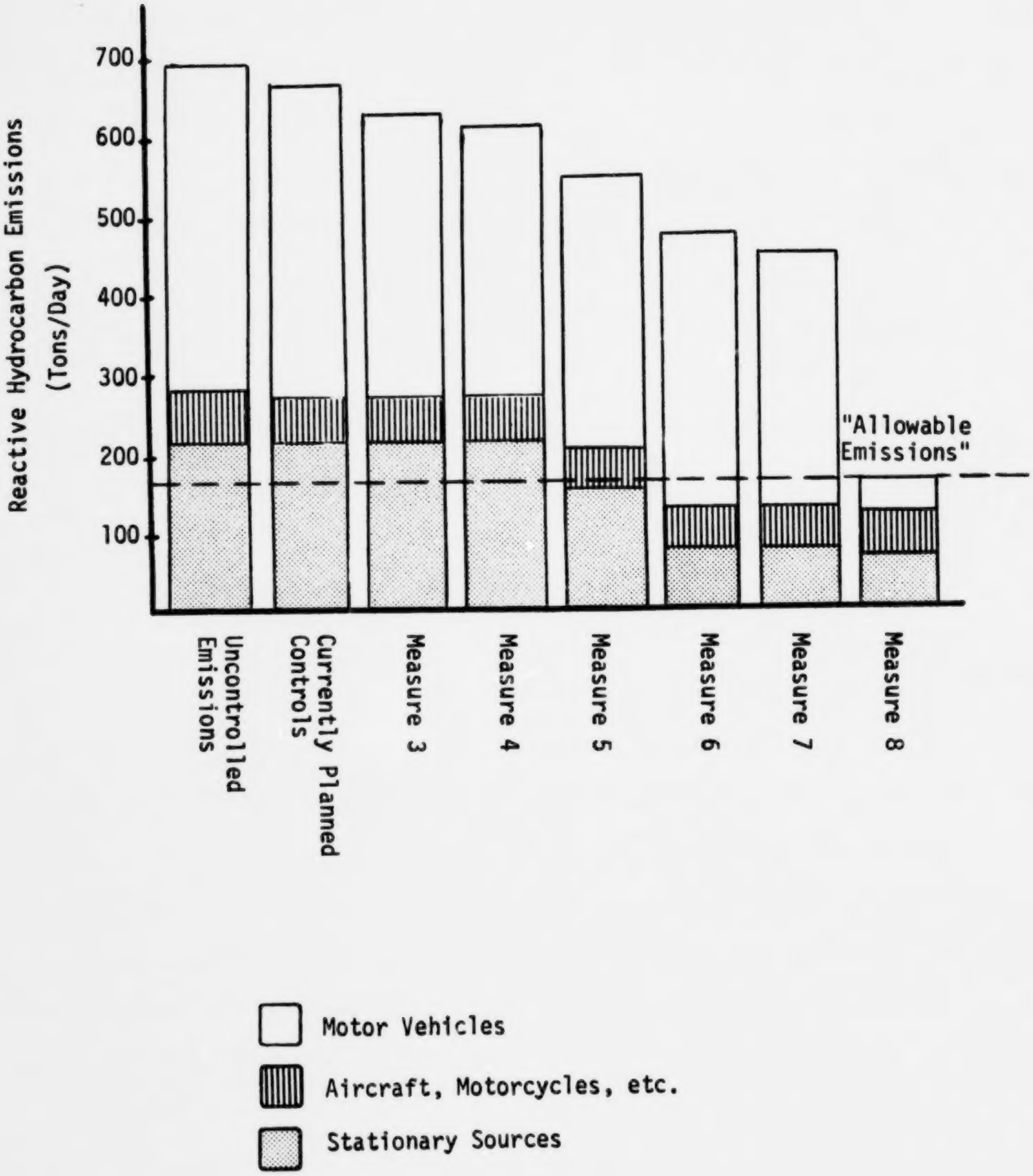
Socio-Economic Obstacles — Obstacles involving the impact of control measures on the public, commerce, and industry.

Political Obstacles — Obstacles involving the feasibility of productive interaction among appropriate leaders, administrators, legislators, and special interest groups for the purpose of instituting recommended control measures.

1, 2. Evaporative Controls and Oxidizing Catalytic Converters — The acceleration of these two evaluation programs should be possible without major implementation obstacles. Implementation of these programs, however, would require additional legislation due to the estimated costs of these controls.

3. Mandatory Inspection/Maintenance — Would require additional legislation; this might be difficult in view of the fact that three such bills died in the Legislature during 1972 (see Appendix J — Section II).

Figure 10.1 The Impact of Proposed Control Strategy on Reducing Reactive Hydrocarbon Emissions (1977)



A number of studies on the subject have been conducted by the State and the public is apparently ready to accept it. The legislative obstacles are impeding this control measure.

4. Mandatory Conversion of Fleet Vehicles to Burn Gaseous Fuels – Would require additional legislation; again, the Legislature has not been favorable to this type of bill. Reaction from those to be affected has been mixed, ranging from fleets voluntarily converting to gaseous fuels to operators who have come out in public opposition to any such measure.

5. Evaporative Loss Controls – Since several local APCD's have adopted regulations to control these sources, there should only be minor problems in implementing this control measure; presently, the main problem is the availability of hardware to use at the stations and on the automobile fuel tanks.

6. Additional Stationary Source Controls – Presently, under the jurisdiction of the local APCD's, implementation should be possible with the main opposition coming from those sources to be controlled.

7. Mass Transit – This control is out of the jurisdiction of the ARB and would have to be implemented by the transportation agencies of the area (e.g., Southern California Association of Governments, Southern California Rapid Transit District, Orange County Transit District). Improvements of the types required will require additional funding, most probably from the Federal level. The long range planning of transportation agencies may conflict with the short range needs of this program.

8. VMT Reduction – A large scale VMT reduction through gasoline rationing will be extremely difficult to implement. Since nearly everyone will be affected, opposition can be expected on all fronts. Due to the

severity of the measure, the political, institutional, socio-economic constraints are likely to force a reevaluation of the overall program objectives.

10.2 Implementation Time Schedule

The time schedule for implementation of the outlined control measures is presented in Table 10.1. The dates given for the control strategies generally represent "target dates" which would result in the maximum benefit being derived from the program; the necessary lead times have been considered. The following discussions present some considerations which went into the implementation scheduling.

1. Evaporative Control Devices — The currently proposed evaluation program for these devices will probably be completed by late 1973. If warranted upon completion of the study, applications for certification of specific devices will probably take another nine months or so. Since additional legislation would be required for such a retrofit program, the earliest date one would expect such a program to be implemented, if at all, would be early 1975. It is recommended that the study and certification program schedule be accelerated; simultaneously, efforts should be made to obtain the necessary legislation to implement such a program. The passage of time alone eliminates the number of 1966-1969 vehicles. Implementation of this program in 1974 would result in a larger reduction of hydrocarbon emissions from these sources.

2. Oxidizing Catalytic Converters — The current testing program of prototype catalytic converters should be expanded and accelerated to determine their feasibility as a retrofit on 1966-1974 vehicles. If these devices can be proven as workable on a large sample of cars, a

program should be implemented to encourage their use. Additional legislation would again be required to implement a mandatory installation program.

3. Mandatory Inspection/Maintenance — The feasibility and costs for a variety of inspection/maintenance programs have been evaluated in California; however, there has been difficulty in obtaining the required legislation to institute such a measure. The earliest date for implementing such a program in the South Coast Air Basin appears to be 1974-1975.

4. Gaseous Fuel Conversion — To derive the maximum benefit of this program, implementation should begin as soon as possible. Legislation for such a program could not be expected until 1973. Implementation should be completed by January 1975.

5. Evaporative Loss Controls — Currently being held up by the supply of available hardware devices for service stations and non-standardized automobile fuel tank fill pipes.

6. Additional Stationary Source Controls — Although stationary sources are under numerous rules and regulations, as mobile sources come under stringent controls, additional ways will have to be found to further control stationary sources. Especially in the Los Angeles region, new stationary sources should be carefully regulated.

7. Mass Transit — Improvement and expansions are limited by the current supply of buses. The lead time required for a large order of new buses is on the order of two to three years. Legalizing jitney services could be accomplished in a shorter time frame. The legal authority presently exists for establishing exclusive bus and car pool lanes. No specific legal authority is needed to institute park-and-ride facilities.

8. VMT Reduction — If it becomes necessary to implement this control measure, it should be done so gradually. This measure should be used initially as an interim control during the peak oxidant season (May-October). At least one season at a low to moderate level of rationing would be necessary to work out the administrative procedures and to monitor the impacts on the Basin. Again, if necessary, it could be expanded to a year-round program with two levels of rationing — one for the summer season and one for the winter.

Table 10.1 PROPOSED IMPLEMENTATION TIME SCHEDULE

Control Measure	1973	1974	1975	1976	1977	1978	1979	1980
Revised Implementation Plan Submitted to EPA (February 15, 1973)	▲							
Legislative Authority Required for Controls California Air Resources Board								
• Obtain enabling legislation for inspection/maintenance	▲							
• Obtain enabling legislation for gaseous fuel conversion of fleets	▲							
• Obtain enabling legislation for additional retrofit devises (to be used only if proven effective)		▲						
• Obtain enabling legislation for gasoline rationing		▲						
Accelerate Evaporation Controls Evaluation Program (Measure 1)								
• Completion of Evaporative Control Study	▲—▲							
• Certification Program (if warranted)	▲—	—▲						
Accelerate Testing Program for Oxidizing Catalytic Converters (Measure 2)								
• Testing of Devices	▲—▲							
• Certification Program (if warranted)	▲—	—▲						

Table 10.1 PROPOSED IMPLEMENTATION TIME SCHEDULE (CONTINUED)

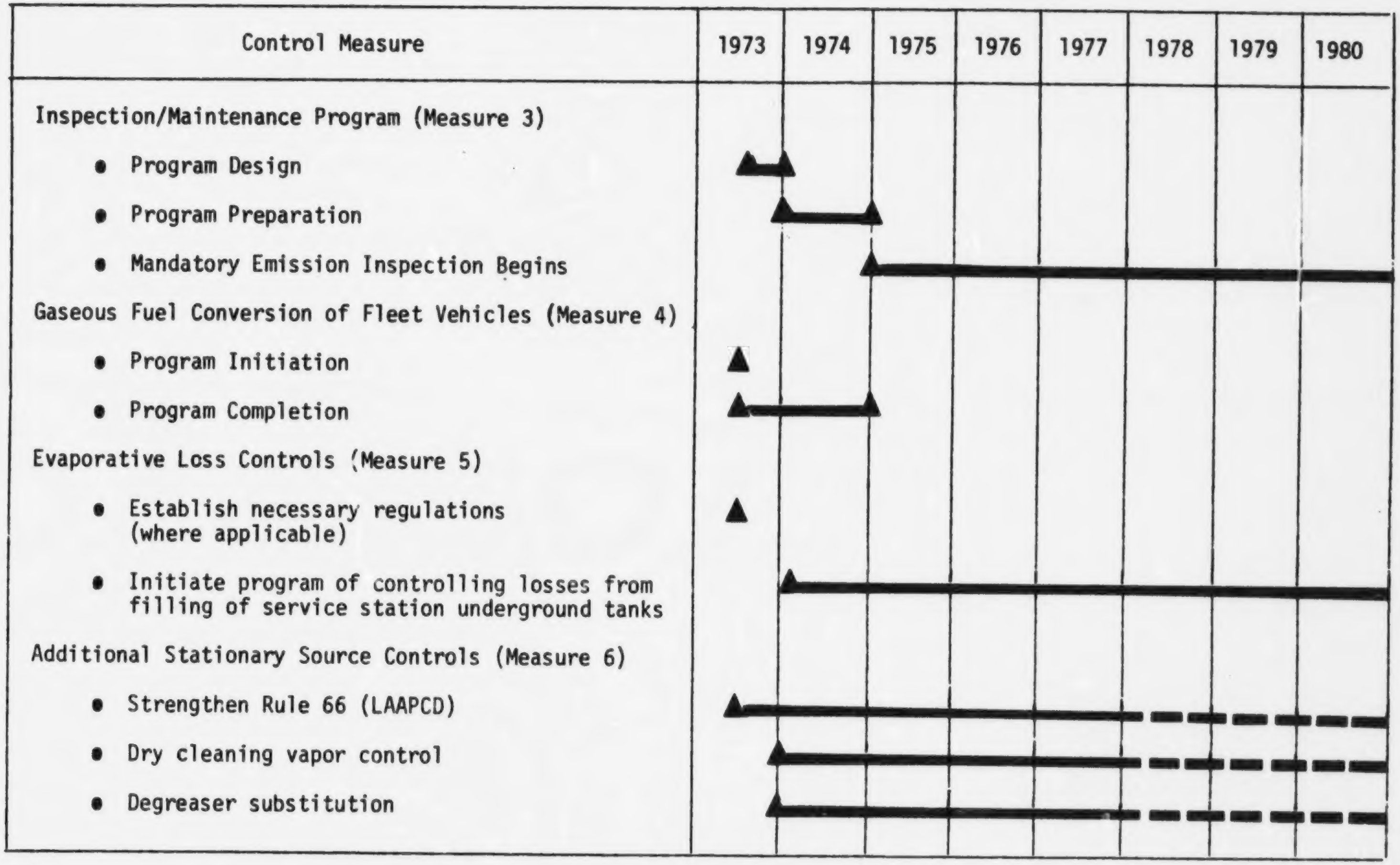
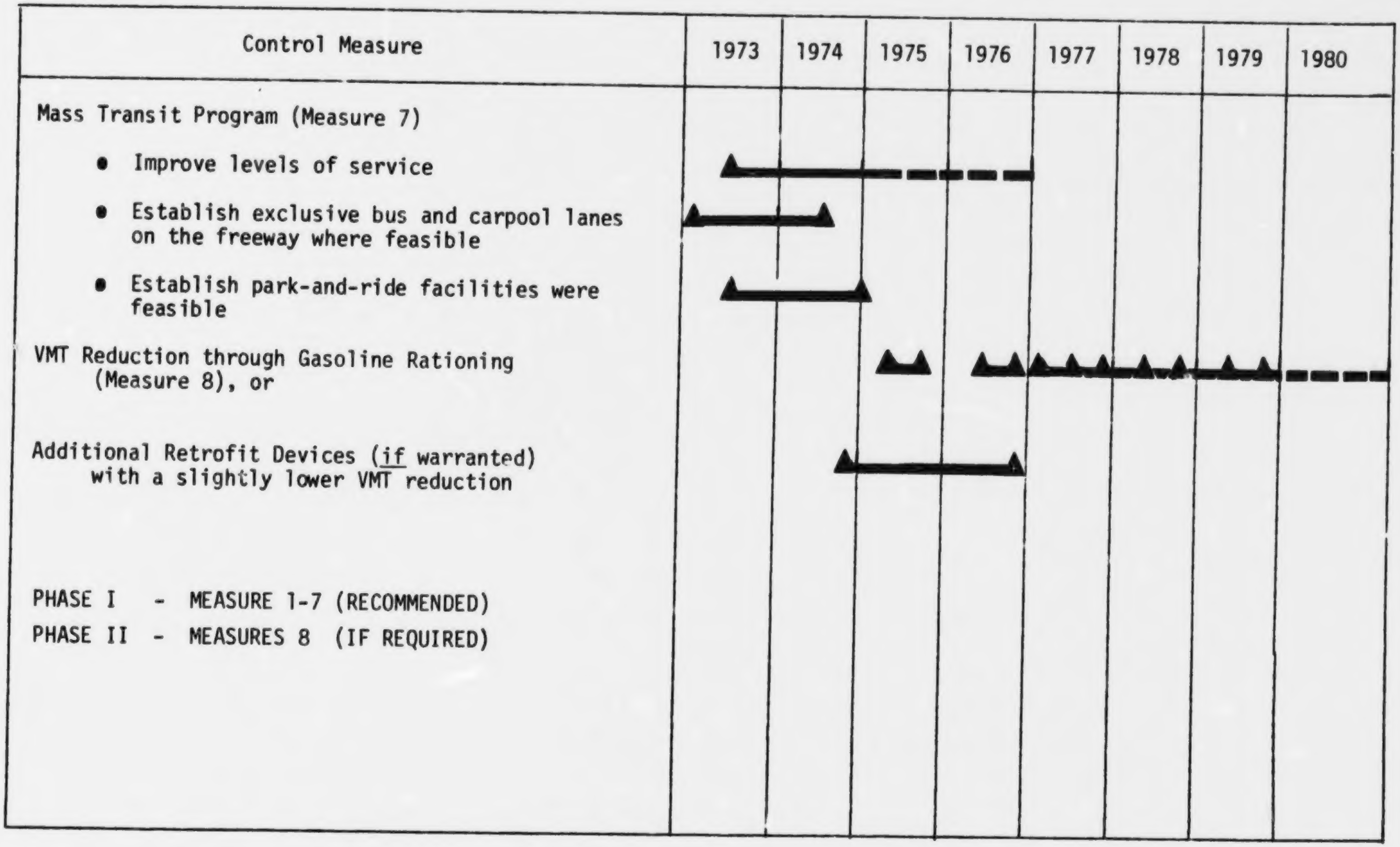


Table 10.1 PROPOSED IMPLEMENTATION TIME SCHEDULE (CONTINUED)



Mass Transit Program (Measure 7)

- Improve levels of service
- Establish exclusive bus and carpool lanes on the freeway where feasible
- Establish park-and-ride facilities were feasible

VMT Reduction through Gasoline Rationing (Measure 8), or

Additional Retrofit Devices (if warranted) with a slightly lower VMT reduction

PHASE I - MEASURE 1-7 (RECOMMENDED)
PHASE II - MEASURES 8 (IF REQUIRED)

Bibliography

1. Administrator of the Environmental Protection Agency, The Economics of Clean Air, Annual Report to the Congress of the United States, March 1972.

2. Altshuller, A. P., W. A. Lonneman, F. D. Sutterfield, and S. L. Kopeznski, "Hydrocarbon Composition of the Atmosphere of the Los Angeles Basin - 1967," Environmental Science and Technology. 5(10): 1009-1016 (1971).

3. Ashabraner, Phil, "Pressures for Better Public Transportation", RPA Planner, vol. #12, January, 1972.

4. Automobile Manufacturers Association, Inc., 1971 Motor Truck Facts.

5. Babcock, R. F. and F. P. Bosselman, paper presented at NSF-Conference on Research Needs in Planning our Physical Environment, Boulder, Colorado, July 23 - August 4, 1972.

6. Blum, E. H., Approaches to Dealing with Motor Vehicle Air Pollution, Rand Corporation, P-3776, December 1967.

7. Board of the Greater Los Angeles Urban Coalition, Summary: Proposed Study of Public Benefit from Increasing Commuter Vehicle Occupancy by 1975 in the Los Angeles Basin, unpublished paper, June 1972.

8. California Air Resources Board, Technical Advisory Committee, Present and Future Options for Air Pollution Control in California, December 1971.

9. ________, Recommended Air Quality Standards Applicable to All Air Basins, September 1970.

10. ________, Addendum to Control of Vehicle Emissions After 1974, July 1971.

11. ________, Control of Vehicle Emissions After 1974, November 1969.

12. California Air Resources Board, Los Angeles County Air Pollution Control District, Western Oil and Gas Association, Gasoline Modification -- Its Potential as an Air Pollution Control Measure in Los Angeles County, November 1969.

13. California Division of Highways, 1971 Traffic Volumes on the California State Highways System, 1971

14. ________, 1971 Travel Time Study - Los Angeles, California, November 1971.

15. ________, LARTS Base Year Report - 1967 Origin - Destination Survey, December, 1971.

16. _______, Los Angeles Area Freeway Surveillance and Control Project (Second Annual Report), January 1972.

17. California Division of Highways - District 7, Freeway Inventory of Geometric Bottleneck Congestion, February 1970.

18. _______, Update on the Program to Upgrade and Control the Los Angeles Freeway Network, January 1972.

19. California Institute of Technology, Environmental Quality Laboratory, Caltech Clean Air Car Project - Gaseous Fuels Manual, Pasadena, California, March 1972.

20. Carlin, A., The Implications of Geographic-Specificity for Air Pollution Abatement Strategy, Rand Corporation, P-4237, October 1969.

21. Carlin, A. P. and G. E. Kocher, Environmental Problems: Their Causes, Cures, and Evolution - Using Southern California Smog as an Example, Rand Corporation, R-640 - CC/RC, May 1971.

22. Carlin, A. and M. Wohl, An Economic Re-Evaluation of the Proposed Los Angeles Rapid Transit System, Rand Corporation, P-3918, September 1968.

23. County of Los Angeles, Air Pollution Control District, Rules and Regulations, 1972.

24. _______, Annual Summary Meteorology, Air Pollution Effects and Contaminant Maxima - Calendar Years 1966-1970, Data Processing and Meteorology Section - Technical Services Division.

25. _______, Profile of Air Pollution Control, 434 South San Pedro Street, Los Angeles, California, 1971.

26. City of Los Angeles Traffic Department, Cordon Count - Downtown Los Angeles, May, 1971.

27. Dales, J. H., Pollution, Property, and Prices, University of Toronto Press, 1968.

28. D'Arge, R. C., "Economic Policies, Environmental Problems, and Land Use: A Discussion of Some Issues and Strategies in Research," presented at NSF-Conference on Research Needs in Planning our Physical Environment, Boulder, Colorado, July 25 - August 5, 1972.

29. D'Arge, R., T. Clark, and O. Bubik, "Automotive Exhaust Emission Taxes: Methodology and Some Preliminary Tests," in Project Clean Air-Research Reports, Volume 3, University of California, September 1970.

30. "Effect of Changing Gas Volatility on Refining Costs," Chemical Engineering Progress, 65(2):51-58 (1969).

31. The Environmental Protection Agency, "Conversion of Motor Vehicles to Reduce Air Pollution," (Position Paper), April 1972.

32. The Environmental Quality Laboratory Staff, Smog: A Report to the People of the South Coast Air Basin, EQL Report No. 4, California Institute of Technology, 1972.

33. Eschenroeder, A. Q. and J. R. Martinez, Further Development of the Photochemical Smog Model for the Los Angeles Basin, General Research Corporation, CR-1-191, March 1971.

34. Fort, D. M., W. A. Niskanen, A. H. Pascal, and W. F. Sharpe, Proposal for a "Smog Tax", Rand Corporation, P-1621-RC, February 1959.

35. GSA Sponsored Symposium, Gaseous Fueled Vehicles and the Environment, selected papers from the GSA sponsored symposium, May 24, 25, 26, 1972, Washington, D. C.

36. Gold, D., "Public Concerns and Beliefs About Air Pollution in California: A Statewide Survey," in Project Clean Air-Research Reports, Volume 3, University of California, 1970.

37. Goldman, M. I., Controlling Pollution - The Economics of a Cleaner America, Prentice-Hall, Inc., 1967.

38. Haase, R. H., Are We Willing to Pay for Congestion - Free Transportation?, Rand Corporation, P-2813, January 1964.

39. Haskel, E. H., "State Governments Tackle Pollution," Environmental Science and Technology, 5(11):1092-1097, 1971.

40. Institute of Gas Technology, Emission Reduction Using Gaseous Fuels for Vehicular Propulsion, June 1971.

41. Institute of Public Administration, Teknekron, Inc., and TRW, Inc., Evaluating Transportation Control to Reduce Motor Vehicle Emissions in Major Metropolitan Areas, Interim Report, March 1972.

42. Kagan, D., D. Newman, S. Sander, and B. Walstoncroft, Mass Transit in Los Angeles: An Analysis, Program in Public Policy Studies of the Claremont Colleges, June 1972.

43. Kearin, D. H. and Lamoureaux, R. L., A Survey of Average Driving Patterns in the Los Angeles Urban Area, System Development Corporation Technical Memo (TM(L) - 4119/000/01), February 1969.

44. Kramer, M., L. J. Bintz, and T. A. Tappenden, LP-Gas and the Automobile Club of Southern California, Automotive Engineering Department Automobile Club of Southern California, June 1972.

45. Lee, D. B., Consequences of Service Reductions in Municipal Transit: San Francisco's Muni, Institute of Urban and Regional Development University of California, Berkeley, Working Pater No. 193, September 1972.

46. Lees, Lester, et al, *SMOG: A Report to the People*, Environmental Quality Laboratory, California Institute of Technology, 1972.

47. Martinez, J. R., R. A. Nordsieck, and A. Q. Eschenroeder, *Morning Vehicle - Start Effects on Photochemical Smog*, General Research Corporation, CR-2-191, June 1971.

48. Mayor and Council of the City of Riverside, *Air Pollution Smog - An Existing Health Hazard - An Imminent Disaster*, June 1972.

49. Meyer, J. R., J. F. Kain, and M. Wohl, *The Urban Transportation Problem*, Harvard University Press, 1965.

50. "Mini-Veter$^{\text{T.M.}}$ Catalytic Converter Emission Control Systems," Universal Oil Products Company, November 1972.

51. Motor Vehicle Manufacturers Association of the U. S., Inc., *1972 Automobile Facts and Figures*.

52. Nelson, E. E., "Hydrocarbon Control for Los Angeles by Reducing Gasoline Volatility," presented at the International Automotive Engineering Congress, Detroit, Michigan, January 13-17, 1969.

53. Newman, Leonard, Dunnet, Alex M., and Meis, Gerald J., "An Evaluation of Ramp Control on the Harbor Freeway in Los Angeles," *Highway Research Record*, #303, 1969.

54. The Northern Virginia Transportation Commission, *The Shirley Highway Express Bus-on-Freeway Demonstration Project - A Summary of the First Year of Operation*, June 1972.

55. Northrup Corporation with Olson Laboratories, Inc., *Mandatory Vehicle Emission Inspection and Maintainence*, Part A - Feasibility Study Volume 1, Summary, May 1971.

56. ______, *Mandatory Vehicle Emission Inspection and Maintainence*, Part B - Final Report, Volume V, Part 1, Summary, December 1971.

57. Office of Business Economics, U. S. Department of Commerce, *Economic Projections for Air Quality Control Regions*, National Technical Information Service, PB 195805, June, 1970.

58. Panger, J., "Idle Emissions Testing," S.A.E. Paper No. 720937, October, 1972.

59. Papetti, R. A. and F. R. Gilmore, *Air Pollution*, Rand Corporation P-4571, February 1971.

60. Refinery Management Services Co., *Motor Fuel Vapor Emission Control Study* (Draft Report), October 1972.

61. Report of the Legislative Analyst to the Joint Legislative Budget Committe, *Analysis of the Budget Bill of the State of California for the Fiscal Year July 1, 1972 to June 30, 1973*, California Legislature 1972 Regular Session, 1972.

62. Report of the Panel on Automotive Fuels and Air Pollution, *Automotive Fuels and Air Pollution*, U. S. Dept. of Commerce, March 1971.

63. Rose, A. H., R. Smith, W. F. McMichael, and R. E. Kruse, "Comparison of Auto Exhaust Emissions from Two Major Cities," presented at the Air Pollution Control Association Annual Meeting, Houston, Texas, June 1964.

64. Shooter, D. and A. Kalelkar, *The Benefits and Risks Associated with Gaseous Fueled Vehicles*, Arthur D. Little, Inc., Case 74400-2, May, 1972.

65. "Solvent Vapors Under Fire," *Environmental Science and Technology*, *5*(11):1086-1087, 1971.

66. Southern California Association of Governments, *Employment Projections for the SCAG Area*, (unpublished information) November 1972.

67. Southern California Rapid Transit District, *Fast Facts on the RTD*, April 1971.

68. Southern California Rapid Transit District, California Division of Highways - District 7, *San Bernardino Freeway Express Busway Project - Facts at a Glance*, January 1972.

69. "Standards for Motor Vehicle Fuels", Subchapter 5, Section 2251 from Register 72, No. 31, July 29, 1972.

70. State of California, Department of Motor Vehicles, *Projected Motor Vehicle Registration and Drivers Licenses Outstanding 1970-1985*, Report No. 31, March 1970.

71. State of California, Environmental Quality Study Council, *Progress Report*, February 1971.

72. State of California, Governor's Task Force on Periodic Vehicle Inspection and Maintainence for Emissions Control, *Task Force Report on Periodic Vehicle Inspection and Maintainence for Emissions Control, and Recommended Program*, October 1972.

73. State of California, The Resources Agency, Air Resources Board, *Air Pollution Control in California 1970*, January 1971.

74. ________, *Air Pollution Control in California 1971*, January 1972.

75. ________, "Effect of Speed on Emissions," Project M-220, March 1971.

76. ________, California Emission Inventory 1970, July 1972, pp.41-52.

77. ________, "Modification or Conversion of Vehicles to Operate on Natural Gas or Liquid Petroleum Gas Fuel," November 1, 1971.

78. ________, "Status Report on Used Car Devices," February 16, 1972.

79. ________, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972.

80. "Statement on Cost of Changing Fuel Composition," November 10, 1969 (author unknown).

81. Systems Applications, Inc., Development of a Simulation Model for Estimating Ground Level Concentrations of Photochemical Pollutants, Report 71 SAI-21, July 1971.

82. Transportation for the Future: Mass or Mess? A special conference on transportation, October 19, 1972, Los Angeles, California.

    a. Moorehead, J. D., "A Paper on Funding Transportation in California"

    b. Ralph, E., "Article 26: Obstacle to Improved Transportation in California"

    c. Ackermann, W. O., "Southern California Regional Transportation Planning"

    d. Siegel, B., "Regional Transportation Planning in Southern California Comment, Critique and a New Approach"

83. Trijonis, John C., An Economic Air Pollution Control Model Application: Photochemical Smog in Los Angeles County in 1975, Ph.D. Thesis, California Institute of Technology, Pasadena, California, 1972.

84. U. S. Government, General Services Administration, A Report on the General Services Administration's Dual-Fuel Vehicle Experiment - Pollution Reduction with Cost Savings.

85. Voelz, F. L., et al, "Exhaust Emission Levels of In-Service Vehicles - Comparison of 1970 and 1971 Surveys,"S. A. E. Paper No. 720498, May, 1972.

86. Alan M. Voorhees and Associates, Inc., Los Angeles Mode Choice Model Development Study, February, 1972.

87. West, John and Schaefer, Bill, Developing a Freeway Traffic Management System for Los Angeles, Presentation to A.A.S.H.O., Houston, Texas, November, 1970.

88. Personal communications with California Division of Highways - District 7 staff personnel, October 1972.

89. Personal communications with Southern California Rapid Transit District staff personnel, October, 1972.

90. Personal communications with Orange County Transit District staff personnel, October, 1972.

91. Personal communications with the Traffic Engineer, City of Los Angeles, November, 1971.

92. Personal communications with California Division of Highways, District 7, Advance Planning staff personnel, November, 1972.

93. Branch, M.C. and E.Y. Leong (eds.), Research Investigation-Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972.

94. California Air Resources Board, Technical Advisory Committee, Emission Control of Used Cars; Available Options: Their Effectiveness, Cost and Feasibility, June, 1971.

95. State of California, The Resources Agency, Air Resources Board, "A Report to the Legislature on Vehicle Emission Inspection," July 1, 1971.

APPENDIX A

AIR QUALITY STANDARDS AND EMISSION INVENTORY

TABLE A-1

NATIONAL AMBIENT AIR QUALITY STANDARDS

(Primary-protective of public health)

POLLUTANT	LEVEL NOT TO BE EXCEEDED[1]
Sulfur Dioxide (SO_2)	80 $\mu g/m^3$ (0.03 ppm)[2]
	365 $\mu g/m^3$ (0.14 ppm)[3]
Particulate Matter	75 $\mu g/m^3$[4]
	260 $\mu g/m^3$[3]
Carbon Monoxide (CO)	10 mg/m^3 (9 ppm)[5]
	40 mg/m^3 (35 ppm)[6]
Photochemical Oxidants	160 $\mu g/m^3$ (0.08 ppm)[6]
Hydrocarbons	160 $\mu g/m^3$ (0.24 ppm)[7]
Nitrogen Oxides	100 $\mu g/m^3$ (0.05 ppm)[2]

[1] $\mu g/m^3$ (micrograms per cubic meter of air, $10^{-6} g/m^3$); ppm (parts per million of air); mg/m^3 (milligrams per cubic meter of air, $10^{-3} g/m^3$)

[2] Annual arithmetic mean.

[3] Maximum 24-hour concentration not to be exceeded more than once a year.

[4] Annual geometric mean.

[5] Maximum 8 -hour concentration not to be exceeded more than once a year.

[6] Maximum one-hour concentration not to be exceeded more than once a year.

[7] Maximum 3-hour concentration (6-9 a.m.) not to be exceeded more than once a year.

Source: See Reference A-1

TABLE A-2

CALIFORNIA AMBIENT AIR QUALITY STANDARDS

POLLUTANT	CONCENTRATION	DURATION OF AVERAGING PERIOD
Oxidant, including ozone (O_3)	0.10 ppm	1 hour
Carbon Monoxide (CO)	10 ppm	12 hours
	40 ppm	1 hour
Sulfur Dioxide (SO_2)	0.5 ppm	1 hour
	0.04 ppm	24 hours
Visibility-Reducing Particulates	Insufficient amount to reduce the prevailing visibility to 10 miles when relative humidity is less than 70%*	1 observation
Suspended Particulate Matter	60 $\mu g/m^3$	24-hour sample, annual geometric mean
	100 $\mu g/m^3$	24-hour sample
Lead (particulate)	1.5 $\mu g/m^3$	30-day average
Hydrogen Sulfide (H_2S)	0.03 ppm	1 hour
Nitrogen Dioxide (NO_2)	0.25 ppm	1 hour

*Prevailing visibility is defined as the greatest visibility which is attained or surpassed around at least half of the horizon circle, but not necessarily in continuous sectors.

Source: See Reference A-2.

TABLE A-3

SOUTH COAST AIR BASIN EMISSION INVENTORY (1970)

Emission Source (Tons/Day)	Organic Gases			Parti- culate Matter	Oxides of Nitrogen	Sulfur Dioxide	Carbon Monoxide
	Reactivity						
	High	Low	Total				
STATIONARY SOURCES							
PETROLEUM							
Production		114	114	0.4	27.9	5.5	
Refining	5.0	40.0	45.0	5.0	22.0	50.0	5.0
Marketing	68.1	79.5	148		11.0		
SUBTOTAL	73.1	234	307	5.4	60.9	55.5	5.0
ORGANIC SOLVENT USERS							
Surface Coating	49.2	201	250	15.0			
Dry Cleaning	6.1	26.1	32.2				
Degreasing	22.6	82.6	105				
Other	32.9	140	173	6.0		1.0	
SUBTOTAL	110	450	560	21.0		1.0	
CHEMICAL				0.5	0.2	115.0	
METALLERGICAL				21.3	3.0	32.9	3.0
MINERAL		1.0	1.0	26.5	5.5	0.8	
INCINERATION							
Open Burning (dumps)	0.2	2.0	2.2	0.7	0.3	0.1	4.0
Open Burning (backyard)	1.2	13.0	14.2	4.7	2.3	0.2	34.4
Incinerators		1.2	1.2	1.2	1.2		1.3
Other	0.5	4.3	4.8	10.2	2.4		30.0
SUBTOTAL	1.9	20.5	22.4	16.8	6.2	0.3	69.7

TABLE A-3 - STATIONARY SOURCES (Continued)

Emission Source	Organic Gases			Parti-culate Matter	Oxides of Nitrogen	Sulfur Dioxide	Carbon Monoxide
	Reactivity						
	High	Low	Total				
COMBUSTION OF FUELS							
Steam Power Plants	0.2	6.8	7.0	7.8	135	40.9	
Other Industrial	0.1	6.7	6.8	9.8	88.8	9.5	1.1
Domestic and Commercial	0.2	0.2	0.4	9.8	60.1	0.6	0.4
SUBTOTAL	0.5	13.7	14.2	27.4	284	51.0	1.5
AGRICULTURE							
Debris Burning	0.9	7.1	8.0	4.6	0.5		24.1
Orchard Heaters		5.0	5.0	3.8		1.6	
Agricultural Product Processing Plants	8.9	0.5	9.4	0.9			
SUBTOTAL	9.8	12.6	22.4	9.3	0.5	1.6	24.1
TOTAL STATIONARY SOURCES	195	732	927	128	360	258	103
MOBILE SOURCES							
MOTOR VEHICLES							
Gasoline Powered							
Exhaust	1200	401	1600	62.4	951	34.9	10,800
Blowby	51.3	16.9	68.2				
Evaporation	360	154	460				
Diesel Powered		51.7	51.7	16.8	229	16.8	218
SUBTOTAL	1560	623	2180	79.2	1180	51.7	11,000
AIRCRAFT							
Jet Driven	21.7	36.6	58.3	23.8	13.1	3.0	44.1
Piston Driven	11.3	16.3	27.6	0.2	7.3	1.0	155
SUBTOTAL	33.0	52.9	85.9	24.0	20.4	4.0	199
SHIPS AND RAILROADS		5.4	5.4	3.6	6.2	1.1	9.2
TOTAL MOBILE SOURCE	1590	681	2270	107	1210	56.9	11,200
GRAND TOTAL	1790	1410	3200	235	1570	315	11,300

Source: See Reference A-3

TABLE A-4

SOUTH COAST AIR BASIN
Comparison of Emissions by County
(Tons per Day)
1970

County	Total Organic Gases	Parti-culate Matter	Nitrogen Oxides	Sulfur Dioxide	Carbon Monoxide	Total Emissions
Los Angeles*	2,380	129	1,140	250	8,080	12,000
Orange	379	22.5	190	15.1	1,620	2,240
Riverside*	107	18.8	46.7	3.7	433	609
San Bernardino*	144	32.5	85.5	39.5	596	898
Santa Barbara*	47.0	3.9	22.7	1.4	71.8	147
Ventura	135	28.8	76.0	5.2	477	722
Total	3,200	235	1,570	315	11,300	16,600

*That portion of the county within the South Coast Air Basin.

Source: See Reference A-3

References:

A-1. Environmental Protection Agency, "National Primary and Secondary Ambient Air Quality Standards, "Federal Register, Vol. 36, No. 84, April 30, 1971, p. 8187.

A-2. State of California, The Resources Agency, Air Resources Board, Air Pollution Control in California - 1970, 1970 Annual Report, January, 1971, p. 24.

A-3. State of California, The Resources Agency, Air Resources Board, California Emission Inventory - 1970, July 1972, pp. 43, 46.

APPENDIX B

AIR QUALITY - DATA, MONITORING STATIONS AND METHODS

This appendix is divided into three short sections. Section I provides a slightly more detailed breakdown of air quality violations and levels as experienced in Los Angeles County. Similar data exists for the other counties of the South Coast Air Basin as well. The severity of the problem is self evident from the data. Section II illustrates graphically the locations of various air quality monitoring stations around the Basin. Section III summarizes in table format, the air quality monitoring techniques presently being used by the State and Los Angeles County Air Pollution Control District.

TABLE B-1

I. AIR QUALITY DATA - LOS ANGELES COUNTY

CARBON MONOXIDE

Number of Days on Which State Standard for CO was Equalled or Exceeded (10 ppm Average for 12 Hours)

LOS ANGELES BASIN

MONTH	YEAR 1965	1966	1967	1968	1969	1970
JAN.	31	31	31	31	20	27
FEB.	28	28	28	29	15	22
MAR.	31	31	31	31	19	18
APR.	30	30	30	12	4	12
MAY	31	31	31	2	3	8
JUNE	30	30	30	1	2	3
JULY	31	31	31	1	4	7
AUG.	31	31	31	3	12	12
SEPT.	30	30	30	9	14	20
OCT.	31	31	31	15	24	20
NOV.	30	30	30	24	26	27
DEC.	31	31	29	27	28	27
TOTAL	365	365	363	185	171	203

Source: see Reference B-1

NITROGEN DIOXIDE

Table B-2. Number of Days on Which State Standard for Nitrogen Dioxide Was Equalled or Exceeded (Hourly Average - 0.25ppm)

LOS ANGELES BASIN

	YEAR						
MONTH	1964	1965	1966	1967	1968	1969	1970
JAN.	8	13	10	14	15	8	9
FEB.	12	11	7	17	13	3	10
MAR.	3	2	12	7	10	6	5
APR.	4	5	4	0	6	3	3
MAY	3	1	1	3	5	4	9
JUNE	4	1	2	3	11	1	4
JULY	6	5	10	9	14	10	13
AUG.	3	11	5	9	7	14	9
SEPT.	9	11	9	6	11	16	19
OCT.	16	22	12	22	13	11	12
NOV.	6	8	7	14	15	16	16
DEC.	4	10	10	9	12	10	6
TOTAL	78	100	89	113	132	102	115

Source: see Reference B-1

OXIDANT

Table B-3. Number of Days on Which State Standard for Total Oxidant (Kl Method) Was Equalled or Exceeded
(Hourly Average - 0.10 ppm)

LOS ANGELES BASIN

	YEAR						
MONTH	1964	1965	1966	1967	1968	1969	1970
JAN.	9	9	11	10	8	8	5
FEB.	16	17	13	22	13	7	11
MAR.	12	10	23	18	18	17	19
APR.	15	17	26	14	24	22	19
MAY	22	21	26	22	26	26	26
JUNE	27	25	29	24	26	22	27
JULY	31	31	31	31	31	30	31
AUG.	30	31	31	31	29	31	31
SEPT.	30	24	28	28	25	30	29
OCT.	27	28	30	31	26	27	24
NOV.	10	15	17	20	20	14	17
DEC.	3	8	6	8	6	12	2
TOTAL	232	236	271	259	252	246	241

Source: see Reference B-1

Note: California's air quality standards were promulgated before the federal ambient air quality standards and consequently, much of the State's air quality data base uses the State standards as a reference.

OZONE

Table B-4. Number of Days Each Month During 1969 and 1970 on Which the Daily Instantaneous Maximum Ozone Concentration (Kl Method) Equalled or Exceeded Levels Indicated

LOS ANGELES BASIN

MONTH	1969 CONCENTRATION, PPM					1970 CONCENTRATION, PPM				
	0.10	0.15	0.25	0.35	0.40	0.10	0.15	0.25	0.35	0.40
JAN.	8	4	0	0	0	8	2	0	0	0
FEB.	9	2	0	0	0	15	9	1	0	0
MAR.	19	13	5	1	1	21	12	3	0	0
APR.	23	15	3	0	0	21	13	3	0	0
MAY	27	24	16	5	2	29	22	7	4	2
JUNE	25	19	5	2	1	27	23	13	7	6
JULY	30	30	24	7	4	31	31	27	10	5
AUG.	31	31	31	19	7	31	31	30	10	6
SEPT.	30	28	23	15	10	29	29	21	9	7
OCT.	28	20	5	0	0	25	20	8	1	1
NOV.	16	9	3	0	0	19	11	2	0	0
DEC.	17	5	0	0	0	8	0	0	0	0
TOTAL	263	200	115	49	25	264	203	-15	41	27

Source: see Reference B-1

II. Ambient Air Quality Monitoring Stations - South Coast Air Basin

During 1970, the ARB compiled air quality data for the South Coast Air Basin from 40 monitoring stations. The breakdown of these stations is given in Table B-5. The locations are illustrated in Figure B-1.

TABLE B-5

Air Quality Monitoring Stations - South Coast Air Basin (1970)

Agency	No. of Stations
Los Angeles County APCD	12
Orange County APCD	4
Riverside County APCD	2
San Bernardino County APCD	4
Ventura County APCD	5
University of California at Riverside	1
ARB	1
NASN-EPA	11
Total	40

Source: see Reference B-2

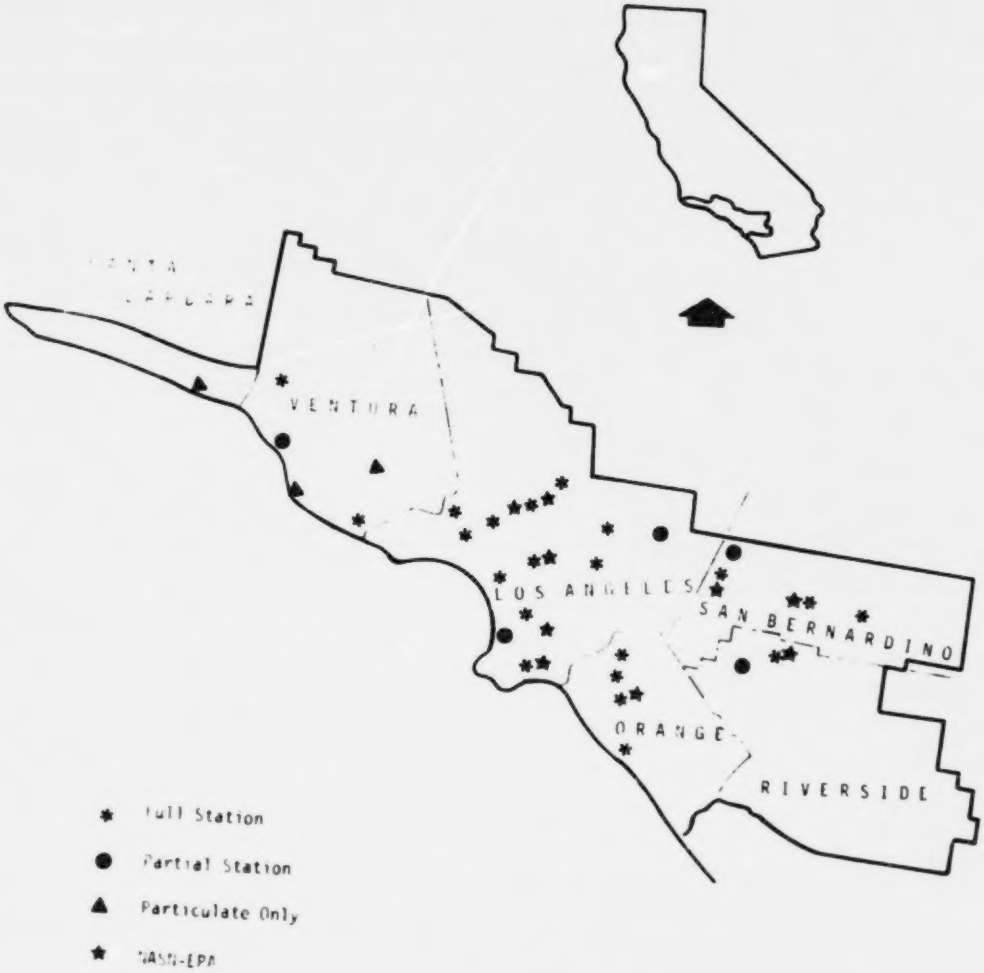

SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
* Full Station
● Partial Station
▲ Particulate Only
★ NASN-EPA

Figure B-1. Location of Air Quality Monitoring Stations (South Coast Air Basin - 1970)

Source: See Reference B-2

III. Federal, State, and Local Air Quality Monitoring Reference Methods

Various agencies have adapted different reference methods for monitoring ambient air quality. In part, this is due to the constant change and improvement in methods which have become available. The differences between agencies, is often due to practical considerations such as budgetary constraints. The following tables summarize the reference methods which have been adapted by various levels of government.

The Environmental Protection Agency (EPA) has recently issued a series of reference methods applicable to those pollutants for which primary and secondary ambient air quality standards have been established. A listing of these methods as well as the EPA standards is given in Table B-6.

Table B-6. National Air Quality Standards and Reference Methods

Pollutant	Primary Standards	Averaging Times	Reference Method	Principle of Detection
SO_2	0.03 ppm	Annual mean	Pararosaniline	Colorimetric
	0.14 ppm	24 hours	"	"
Particulate Matter	74μg/m^3	Annual mean	"Hi-vol" sampler	Gravimetric
	260μg/m^3	24 hours	"	"
CO	9 ppm	8 hours	Nondispersive IR	Infrared
	35 ppm	1 hour		
Photochemical Oxidants	0.08 ppm	1 hour	Gas phase O_3-C_2H_4	Chemiluminescence
HC	0.24 ppm	3 hours	Gas chromatography	Flame ionization
NO_2	0.05 ppm	Annual mean	24-hour integrated samples collected	Colorimetric

Source: see Reference B-3

In addition to the specified reference methods, provisions have been made for "equivalent methods" to be used for air quality measurements. The "equivalent methods" supposedly yield results consistent with those obtained by the reference method. Establishing equivalency sometimes is based on the judgment of "experts" in the field rather than upon detailed experimental evidence.

In California, air pollution control is primarily the responsibility of the Air Resources Board (ARB). The ARB has likewise adopted a series of methods to be used for monitoring air quality. Table B-7 summarizes California's most recent standards and methods of analysis. Again, "any equivalent procedure which can be shown to the satisfaction of the Air Resources Board to give equivalent results...may be used (B-4)."

Table B-7. California Air Quality Standards and Reference Methods

Pollutant	Standards	Averaging Times	Reference Method	Principle of Detection
SO_2	0.04 ppm	24 hours	Conductimetric	Conductimetric
	0.5 ppm	1 hour	"	"
Visibility reducing particles	In sufficient amount to reduce the prevailing visibility to 10 miles when the relative humidity $<70\%$	1 observation	Trained observer	Human observation
Oxidant, including O_3	0.10 ppm	1 hour	Neutral buffered KI	Colorimetric
NO_2	0.25 ppm	1 hour	Saltzman	Colorimetric
Lead (particulate)	1.5 $\mu g/m^3$	30 days	"Hi-vol" sampler, dithiozone	Colorimetric
H_2S	0.03 ppm	1 hour	Stractan, $Ca(OH)_2$	Colorimetric

Source: see Reference B-4

The ARB maintains and operates 30 fixed and 5 mobile stations in its State Air Monitoring Network. In addition to these 35 stations, 40 other air monitoring stations are independently operated by local districts, primarily Air Pollution Control Districts. The largest of these control districts is the Los Angeles County Air Pollution Control District (LAAPCD), which monitors air quality in the South Coast Basin. The methods currently in use by the LAAPCD are outlined below (Table B-8). The definitions of the principle of detection appear in Table B-9.

Table B-8. LAAPCD - Methods Employed for Ambient Air Monitoring

Pollutant	Reference Method	Principle of Detection
SO_2	H_2O_2 oxidation, electrolytic conductivity	Conductrimetric
Particulate matter	Coefficient of mass (K_m) or soiling index	Light reflectance
Filterable aerosols	"Hi-vol" sampler	Gravimetric
CO	Nondispersive IR	Infrared
O_3 (oxidant)	Neutral KI titration	Colorimetric
HC	Gas chromatography	Flame ionization
NO/NO_2	Saltzman	Colorimetric

Source: see Reference B-5

Table B-9. Definitions of Principle of Detection

Principle of Detection	Definition
Colorimetric	The pollutant of interest is bubbled through an appropriate reacting solution, usually containing a complexing reagent; a colored solution is formed, the intensity of which is quantitatively determined in a photometer.
Gravimetric	The pollutant(s) are collected for a specified time period after which they are accurately weighed on an analytical balance. The weight of material accumulated gives an index of the extent of pollution.
Infrared	The pollutant of interest absorbs IR radiation at a series of wavelengths characteristic of the particular pollutant.
Chemiluminescence	The pollutant reacts with another compound to emit light which is measured accurately, with a photomultiplier tube, amplified, and read out electronically.
Flame Ionization	Pollutants present in a hydrogen flame are ionized producing an ion current which is accurately monitored. The magnitude of the ion current produced is directly proportional to the pollutant concentration.
Conductimetric	The pollutant reacts to form a strong electrolytic species in solution; then, the conductance of the solution is determined (any ions present; e.g., NO_3^-, Br^-, $C\ell^-$, OH^- in the solution will be measured).
Coulometric	The pollutant reacts in aqueous solution to set off a series of reactions which result in a current being produced. The amount of current produced in the electrochemical cell is measured and related to the original pollutant concentration.

REFERENCES

B-1. County of Los Angeles, Air Pollution Control District, Profile of Air Pollution Control, 1971, pp. 73, 75-77.

B-2. State of California, The Resources Agency, Air Resources Board, The State of California Implementation Plan for Achieving and Maintaining the National Ambient Air Quality Standards, January 30, 1972.

B-3. Environmental Protection Agency, "National Primary and Secondary Ambient Air Quality Standards," Federal Register, 36(84): 8185-8201, April 30, 1971.

B-4. State of California, The Resources Agency, Air Resources Board, Air Pollution Control in California - 1970, 1970 Annual Report, January 1971.

B-5. County of Los Angeles, Air Pollution Control District, Technical Services Division, Atmospheric Analysis Program - Procedures Employed, October 1970.

APPENDIX C

ECONOMIC DATA FOR THE SOUTH COAST AIR BASIN

Table C-1. Population, Personal Income and Earnings, 1967-1980 - United States

Item	1967	1970	1975	1980
Population	197,849,000	204,820,000	219,021,446	234,208,000
Total Personal Income	546,864,730	629,046,000	783,303,783	975,373,000
Total Earnings	440,561,730	503,237,000	621,661,366	770,545,000
Per Capita Personal Income ($58)	2,764	3,071	3,576	4,165
Per Capita Income Relative (US=1.00)	1.00	1.00	1.00	1.00

Source: see Reference C-1

Table C-2. Population, Personal Income and Earnings, 1967-1980 - Sum of Air Quality Control Regions[a]

Item	1967	1970	1975	1980
Population	97,939,836	102,038,853	110,139,251	118,952,331
Total Personal Income	315,968,601	363,165,622	452,781,232	564,896,211
Total Earnings	256,700,068	293,951,116	364,103,413	452,481,535
Per Capita Personal Income ($58)	3,226	3,559	4,111	4,749
Per Capita Income Relative (US=1.00)	1.17	1.16	1.15	1.14

[a] 55 air quality control regions are included in this data representing the majority of the larger metropolitan areas and accounting for approximately 50% of the U.S. population

Source: see Reference C-1

Table C-3. Population, Personal Income and Earnings, 1967-1980 - Air Quality Control Region, Los Angeles, Calif.[a]

Item	1967	1970	1975	1980
Population	9,513,841	10,058,700	11,324,054	12,748,400
Total Personal Income	31,689,388	37,126,505	48,432,384	63,180,948
Total Earnings	25,875,847	30,168,998	38,978,743	50,513,168
Per Capita Personal Income ($58)	3,331	3,691	4,277	4,956
Per Capita Income Relative (US=1.00)	1.21	1.20	1.20	1.19

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[a] the Los Angeles air quality control region in this analysis included the following counties: Los Angeles, Riverside, San Bernardino, Ventura and Orange.

Source: see Reference C-1

Table C-4. Economic Projections - Los Angeles Air Quality Control Region

POPULATION, INCOME AND EARNINGS BY INDUSTRY RELATIVE TO 1967
(1967 = 100.0)

EARNINGS BY INDUSTRY

	1967	1970		1975		1980	
POPULATION			105.7[a]		119.0[a]		134.0[a]
TOTAL PERSONAL INCOME			117.2		152.8		199.4
TOTAL EARNINGS	25,875,847	30,163,998	116.6	38,978,743	150.6	50,513,168	195.2
AGRICULTURE,FORESTRY + FISHERIES	298,517	308,230	103.3	311,898	104.5	315,736	105.8
MINING	140,655	145,813	103.7	161,171	114.6	178,474	126.9
CRUDE PETROLEUM + NAT.GAS	103,770	104,831	101.0	112,746	108.7	121,301	116.9
MINING EXCL. FUELS	36,385	40,982	111.1	48,405	131.2	57,173	155.0
METAL MINING	11,310	13,195	116.7	15,540	137.6	18,350	162.2
NONMETALLIC	25,575	27,787	108.6	32,865	128.4	38,823	151.8
CONTRACT CONSTRUCTION	1,270,195	1,641,636	129.2	2,124,761	167.3	2,749,968	216.5
MANUFACTURING	8,227,576	9,267,283	112.6	11,570,568	140.6	14,475,263	175.9
FOOD + KINDRED PRODUCTS	479,682	511,368	106.6	615,758	128.4	741,456	154.6
TEXTILE MILL PRODUCTS	42,444	47,510	111.9	58,121	136.9	71,102	167.5
APPAREL + OTHER TEXTILES	246,352	271,516	109.3	325,508	131.1	390,455	157.2
PRINTING + PUBLISHING	348,384	387,417	111.2	497,539	142.8	638,961	183.4
CHEMICALS + ALLIED PRODUCTS	247,072	296,879	120.2	382,626	154.9	493,134	199.6
LUMBER + FURNITURE	223,370	249,213	111.6	284,573	127.4	324,836	145.4
MACHINERY, ALL	2,281,514	2,563,283	112.4	3,307,031	144.9	4,268,489	187.1
MACHINERY,EXCL. ELECTRICAL	716,948	798,354	111.4	997,465	139.1	1,246,221	173.8
ELECTRICAL EQUIPMENT + SUPPLIES	1,564,566	1,764,929	112.8	2,309,546	147.6	3,022,268	193.2
TRANSPORTATION EQUIPMENT	1,893,045	2,103,445	111.1	2,506,916	132.4	2,988,368	157.9
MOTOR VEHICLES + EQUIPMENT	162,193	225,045	138.9	279,394	172.3	346,870	213.9
TRANSPORTATION EQUIPMENT,EXCL.	1,730,852	1,878,400	108.5	2,227,522	128.7	2,641,498	152.6
OTHER MANUFACTURING	2,463,713	2,834,052	115.1	3,592,458	145.8	4,558,464	185.0
PAPER + ALLIED PRODUCTS	138,787	151,928	109.5	187,100	134.8	230,412	166.0
PETROLEUM REFINING	153,039	205,982	134.6	236,842	154.8	272,328	177.9
PRIMARY METALS	334,213	373,737	111.8	439,657	131.5	517,175	154.7
FABRICATED METALS + ORDNANCE	1,105,493	1,230,762	111.3	1,573,999	142.4	2,012,973	182.1
MISCELLANEOUS MANUFACTURING	732,181	874,223	119.4	1,154,860	157.7	1,525,576	208.4
STONE, CLAY AND GLASS	187,511	215,723	115.0	269,219	143.6	335,978	179.2
OTHER MISC. MANUFACTURING	544,670	658,500	120.9	885,661	162.6	1,189,598	218.4
TRANSPORTATION,COMM.,+PUBLUTIL.	1,549,965	1,765,636	113.9	2,237,769	144.4	2,837,654	183.1
TRANSPORTATION	892,673	1,021,831	114.5	1,292,536	144.8	1,636,493	183.3
RAILROAD TRANSPORTATION	165,974	158,436	95.5	186,380	112.3	219,250	132.1
TRUCKING + WAREHOUSING	330,922	403,887	122.0	521,737	157.7	673,966	203.7
OTHER TRANSPORTATION SERVICES	395,777	459,508	116.1	584,417	167.7	743,277	187.8
LOCAL AND SUBURBAN TRANSP.	49,261	55,398	112.5	67,179	136.3	81,366	165.1
WATER TRANSPORTATION	68,213	77,078	113.0	94,178	138.0	114,948	168.5
AIR TRANSPORTATION	214,484	252,583	117.8	327,613	152.7	424,931	198.1
MISC. OTHER TRANSP. SERVICES	63,819	74,449	116.7	95,547	149.7	122,054	191.2
COMMUNICATIONS	469,178	526,999	112.3	669,295	142.6	849,910	181.1
UTILITIES (ELEC.,GAS,SANITARY)	188,114	216,806	115.3	275,960	146.7	351,251	186.7
WHOLESALE + RETAIL TRADE	4,461,472	5,176,968	116.0	6,744,787	151.2	8,787,285	197.0
FINANCE,INSURANCE AND REAL ESTATE	1,467,934	1,723,507	117.4	2,162,360	147.3	2,713,024	184.8
SERVICES	4,592,044	5,432,307	119.6	7,360,591	160.3	9,882,294	215.2
TOTAL GOVERNMENT	3,867,489	4,657,598	120.4	6,304,858	163.0	8,573,470	221.7
CIVILIAN GOVERNMENT	3,384,404	4,160,267	122.9	5,750,614	169.9	7,955,807	235.1
FEDERAL GOVERNMENT	768,036	932,295	121.4	1,217,366	158.5	1,589,578	207.0
STATE AND LOCAL GOVERNMENT	2,616,363	3,227,972	123.4	4,533,248	173.3	6,366,229	243.3
ARMED FORCES	483,085	497,331	102.9	554,264	114.7	617,663	127.9

[a] All figures relative to 1967 data.

Source: see Reference C-1

Table C-5. Total Personal Income - Los Angeles County and California (Billions of Current Dollars)

Year	Los Angeles County	California
1950	not available	19.774
1951	not available	22.756
1952	not available	25.214
1953	not available	27.002
1954	not available	27.682
1955	not available	30.378
1956	13.085	33.177
1957	15.387	35.497
1958	15.943	37.361
1959	17.334	47.010
1960	18.071	42.980
1961	19.037	45.678
1962	20.341	49.051
1963	21.580	52.615
1964	22.979	56.570
1965	24.288	60.234
1966	26.098	65.156
1967	27.923	69.936
1968	29.908	76.900
1969	32.407	83.408

Source: see Reference C-2

Table C-6. Projections of Real Per Capita Personal Income (Thousands of 1958 Dollars)

Year	Los Angeles County	California
1970	3.691	3.350
1975	4.277	3.883
1980	4.956	4.500
1990	6.314	5.734

Source: see Reference C-2

Table C-7. Price Index (1957-59 = 100)

Year	Los Angeles County	California
1950	82.4	81.6
1951	89.4	88.4
1952	92.0	91.2
1953	92.8	92.3
1954	92.7	92.3
1955	92.7	92.1
1956	94.1	93.8
1957	97.2	97.1
1958	100.6	100.6
1959	102.2	102.3
1960	104.1	104.3
1961	105.4	105.6
1962	106.6	106.9
1963	108.2	108.4
1964	110.2	110.3
1965	112.5	112.6
1966	114.7	115.0
1967	117.6	118.0
1968	122.2	122.8
1969	128.0	128.9

Source: see Reference C-2

REFERENCES:

C-1. Regional Economics Division, Office of Business Economics, U.S. Department of Commerce, Economic Projections for Air Quality Control Regions, APTD-0596, Washington, D.C., June 1970.

C-2. Branch, M. C. and E. Y. Leong (eds.), Research Investigation - Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972, Appendix G.

APPENDIX D

GOVERNMENTAL ORGANIZATIONS AND TRANSPORTATION FUNDING MECHANISMS

In the South Coast Basin the intertwining of governmental organizations responsible for planning, designing, constructing and funding transportation facilities is extremely complex. Responsibilities and powers range from the federal agencies which have strong controls of "purse strings" to local agencies which set priorities for improvements and construct as the money becomes available.

The flow of money for transportation related activities is extremely important. It is through the regulation of these funds, for example, that regional organizations can derive the power to coordinate the many local transportation organizations, or that local transit operations can hope to maintain service for the many persons unable to own or operate automobiles. Figure D-1 is a flow chart illustrating the flow of monies for transportation in California.

Federal Agencies

The Federal Highway Administration is responsible for allocating money from the Federal Highway Trust Fund. These revenues are derived from a four cents per gallon tax on gasoline and diesel fuel; taxes on trucks, buses, rubber products; and interest (D-1a). The funds are allocated to five federal highway programs: 1) the Federal-aid Primary and 2) Federal-aid Secondary systems which are roads in rural areas; 3) the Federal-aid Urban Extension Programs; 4) Federal-aid Urban Programs and 5) the special TOPICS programs for roads in urban areas. Money from these federally funded programs are filtered down to state and local organizations, and can only be used for initial construction or betterment of a road or highway. Table D-1 lists the amounts and distribution of these federal funds for the 1971-1972 Fiscal Year.

The federal agency responsible for funding public transportation is the Urban Mass Transportation Administration (UMTA). This agency was specially formed by Congress to administer a set amount of funds to local public transit agencies. UMTA grants can be used for capital improvements, demonstration programs to test new system and operational concepts, and transit planning.

Under recent legislation, local agencies cannot receive federal monies unless there is continuous, ongoing planning being performed by the organization and an environmental impact statement written for projects likely to have an environmental impact on the region.

State Agencies

The California Division of Highways under the Business & Transportation Agency is responsible for planning, development, construction, and maintenance of all state and federal highways. Responsibility for route selection and contract control is vested in the California Highway Commission. The Los Angeles area falls within District 7 of the Division of Highways (covering Ventura, Los Angeles and Orange counties). A special staff of District 7 is the Los Angeles Regional Transportation Study, (LARTS). This group develops information on projected federal and state highway needs and coordinates local street requirements with city and county governments.

State funding for construction of highways comes partially from the federal-aid programs. The Division of Highway must match the federal funds for a specific project. This money is derived from the 7 cents per gallon state gasoline and diesel fuel tax. Of the $.07/gallon, $.0361 is used for matching federal funds. The remainder is distributed to counties and cities.

Another source of funds for state highways comes from user taxes on the automobile provided under Article 26 of the State Constitution. "The net proceeds from the registration, weight, and drivers' license fees are distributed first to the Department of Motor Vehicles, the California Highway Patrol and for other vehicle regulatory activities, and the remaining funds are allocated for State highway purposes." (D-1a) These funds are very strongly committed to highway purposes and there have been many attempts to legislate some of these monies for other transportation purposes (e.g. mass transit).

FLOW OF STATE MOTOR VEHICLE FEES AND RELATED

HIGHWAY USER TAXES IN CALIFORNIA FOR THE 1972-197[illegible] FISCAL YEAR

REVENUE FROM CALIFORNIA STATE MOTOR VEHICLE FEES & TAXES

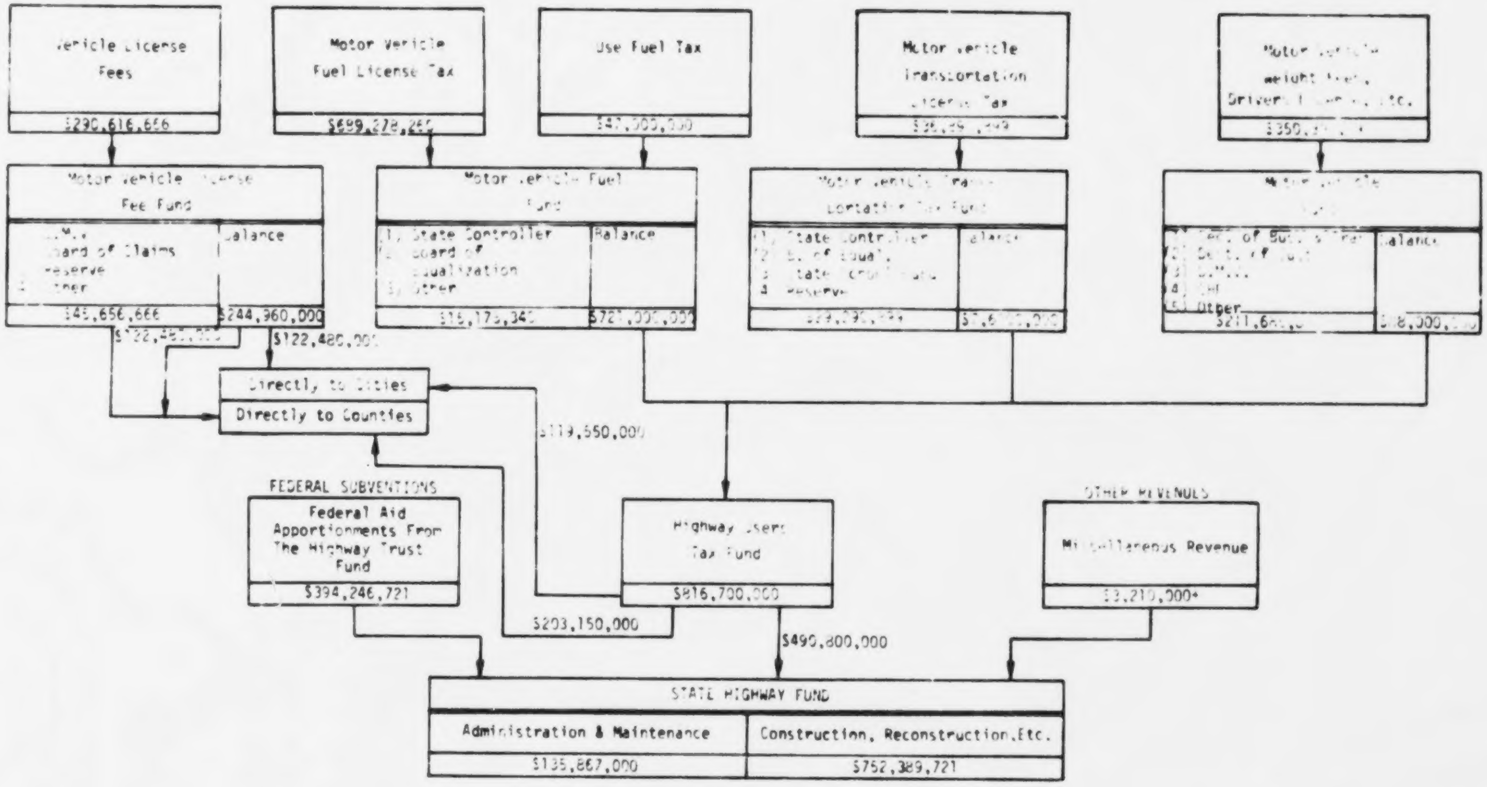
Vehicle License Fees
$290,616,666
Motor Vehicle Fuel License Tax
$699,278,26[illegible]
Use Fuel Tax
$47,000,000
Motor Vehicle Transportation License Tax
$36,[illegible]
Motor Vehicle Weight Fees, Drivers License, Etc.
$350,[illegible]
Motor Vehicle License Fee Fund
D.M.V.
Board of Claims
Reserve
Other
Balance
$45,656,666
$244,960,000
$122,480,000
$122,480,000
Motor Vehicle Fuel Fund
(1) State Controller
(2) Board of Equalization
(3) Other
Balance
$16,173,340
$72[illegible],000,000
Motor Vehicle Transportation Tax Fund
(1) State Controller
(2) B. of Equal.
(3) State Controller
(4) Reserve
Balance
$29,[illegible]
$7,6[illegible],000
Motor Vehicle Fund
(1) Dept. of Bus. & Trans.
(2) Dept. of Just.
(3) D.M.V.
(4) CHP
(5) Other
Balance
$211,6[illegible]
$[illegible]8,000,[illegible]
Directly to Cities
Directly to Counties
$119,550,000
FEDERAL SUBVENTIONS
Federal Aid Apportionments From The Highway Trust Fund
$394,246,721
Highway Users Tax Fund
$816,700,000
$203,150,000
$490,800,000
OTHER REVENUES
Miscellaneous Revenue
$3,210,000+
STATE HIGHWAY FUND
Administration & Maintenance
$135,867,000
Construction, Reconstruction, Etc.
$752,389,721

Figure D-1

Source See Reference D-1a.

TABLE D-1

AMOUNTS AND DISTRIBUTION OF FEDERAL AND STATE FUNDS

1971 - 1972 Fiscal Years
(Millions of Dollars)

Source	Off the Top	DMV	CHP	Schools	City Streets	County Roads	State Hwys
Federal-aid					18	18	354
User Taxes							
Gas & Diesel	13				141	182	388
Reg., Wt., Dr. Lic.	12	63	142				88
Non-User Taxes							
In-lieu	5	9		13	120	120	
Transp. Tax[a]	2			20			5
Totals	$32	$72	$142	$33	$279	$320	$835

[a] In FY72-73, the last year of existence for this tax, its entire net amount will be deposited into the State Highway Fund.

Source: See Reference D-1a

Regional Agencies

In the past decade it has been recognized that there is a need to coordinate the transportation planning activities being performed by the many local agencies. Consequently, the Southern California Association of Governments (SCAG) was organized in 1965 to satisfy federal requirements for establishment of a comprehensive regional plan to allow for receiving federal funds. SCAG is a voluntary association of city and county governments from Ventura, Los Angeles, Orange, San Bernadino, Riverside, and Imperial counties supported by membership dues and federal grants. Transportation planning is only one segment of SCAG and is controlled by the Comprehensive Transportation Committee. Although the research and implementation programs are developed in technical committees under the Comprehensive Transportation Committee, all policies of SCAG become official only upon adoption by SCAG's General Assembly. There is no legislation which lends power to SCAG's policies. SCAG's only power derives from the requirement that all federal grant applications and SB325 claims bear the regional agency's approval.

Local Agencies

On the county level, the Planning Departments and Road Departments handle construction and maintenance of roadways. In the cities the Public Works Departments are responsible for these duties. The City Planning and Traffic Departments evaluate capabilities of existing streets and define requirements for future streets. Each of the county departments is responsible to the county Board of Supervisors and the city departments are responsible to the appropriate city council and Mayor.

Funds for city and county roads and street purposes come from several sources. Some money is made available to them from the State user taxes. Other sources for cities and counties are traffic fines and forfeitures resulting from Vehicle Code violations. Cities are required to use these funds for traffic control, law enforcement and street construction purposes. Fifty percent of county fine and forfeiture funds must be used for construction and maintenance of roads. (D-1a)

Other revenues from the public sector are derived from the sale of street and road bonds and from street and road taxes. Minor amounts come from other governmental and miscellaneous sources (D-1a). Private investment, by developers and others, finance substantial amounts of road and street work.

Public transit agencies in the Los Angeles area exist in two counties and five cities (Long Beach, Santa Monica, Montebello, Torrance and Culver City). The Southern California Rapid Transit District (SCRTD) is a public corporation established by the State Legislature in 1964. This agency has the primary responsibility of planning, developing, constructing and operating public transit in Los Angeles County. In addition, SCRTD provides feeder bus service to certain areas of San Bernadino and Riverside. It is also charged with the responsibility for planning and developing new public transit facilities in the southern portion of Los Angeles County. SCRTD and the Division of Highways are working together to coordinate planning of a regional mass transit system with future highways (SCRTD covers the largest transit area in Southern California; Orange County Transit District is the second largest).

The public transit agencies get their money from various sources. UMTA grants fund several different types of projects -- planning, demonstration, and capital improvement programs. Other federal monies can come from the States and Local Assistance Act of 1972 (Revenue Sharing Funds). Local governments (city and county) are given money according to a specified formula to alleviate problems in eight priority areas. One of these "pirority expenditure" items is "public transportation", including transit systems and streets and roads (D-2). In the Los Angeles area it does not appear that much of this revenue sharing money will be spent directly for public transportation. In the city of Los Angeles Mayor Yorty has proposed to use $14.9 million of the $44.2 million to eliminate a budget deficit (D-3). For the remaining funds, he has suggest 17 other projects for council consideration. Of the $29.3 million dollars remaining Yorty has suggested $0.4 million be spent on public transit.

Although a small portion of the revenue sharing money is directed to public transportation, this money has made other funds available. The

Los Angeles City Director of Finance has revealed that the Los Angeles City Council has reserved money out of its General Fund for the SCRTD (D-4). In Long Beach a similar situation exists. According to the Director of the Finance Department there, the city has not yet established its priority expenditures for the revenue sharing money (D-5). However, the Director suggested that this money has changed the use of the local property tax. From a $.035 tax per $100 assessed valuation, Long Beach is planning to obtain $348,000 in order to reduce fares for senior citizens on the local public transit (D-5).

Another source of funds for local transit in Los Angeles Basin, as in the rest of California, is the Mills-Alquist-Deddeh Act (SB325) passed into law November 4, 1971. Prior to passage of SB325 a sales tax of 5% was imposed on specified items, excluding gasoline. The revenue derived from 4/5 of this tax was placed in the State General Fund. The funds derived from the remaining 1/5 were distributed among the general funds of local government. "Under SB325 the tax rate remains at 5%, but it is also imposed on the sale of gasoline (thereby generating about $180 million per year in additional revenue)(1a)." SB325 alters the distribution of sales tax revenues. The State General Fund now receives revenues derived from 3-3/4 of the 5%, local general funds get 1%, and the remaining revenue (1/4%) is to be used by local governments for public transportation (i.e. public transit systems and streets and roads). The extension of the sales tax to gasoline adds about $31 million allocated to local general funds and provides $138 million per year for local transportation purposes (1a).

Most of the money for local transit comes from the 1/4% portion of the sales tax. In Ventura, Los Angeles, San Bernadino, Orange, Imperial and Riverside Counties SB325 funds are placed in specific local trust funds but the money cannot be used until SCAG has approved the local claim for the money. As with claims for FHWA aid and UMTA grants, SB325 claims are not approved until the locality demonstrates that it is working towards a balanced transportation plan. After July 1, 1975, SCAG will only honor claims that conform to the adopted regional transportation plan.

References

D-1. A Special Conference on Transportation: Transportation for the Future: Mass or Mess?, Los Angeles, California, October 19, 1972.

  a) Moorehead, J. D., "A Paper on Funding Transportation in California."

  b) Ralph, E., "Article 26, Obstacle to Improved Transportation in California."

  c) Ackermann, W. O., Jr., "Southern California Regional Transportation Planning"

  d) Siegel, B., "Regional Transportation Planning in Southern California--Comment, Critique and a New Approach."

D-2. "State and Local Fiscal Assistance Act of 1972", House of Representatives Report No. 92-1450.

D-3. "Yorty Wants Revenue Sharing for $14 Million Budget Deficit,", Los Angeles Times, November 25, 1972.

D-4. Personal communication with the Director of Finance and Budget, Los Angeles City Hall, November, 1972.

D-5. Personal communication with the Finance Director, City of Long Beach, November 1972.

D-6. Southern California Association of Governments, "The Transportation Development Act of 1971 (SB325, 1971): A General Explanation," October, 1972.

APPENDIX E

SAMPLE CALCULATIONS

Sample Calculation #1

VMT Reductions Due to Increases in Transit Ridership

$$VMT = \bar{D}\left(\frac{F_A}{OCA} + \frac{F_T}{OCB}\right)T_P \qquad (1)$$

Where:

$\bar{D}$ = Average distance (miles)

F_A = Fraction automobile passengers

F_T = Fraction transit passengers

T_P = Total passengers

OCA = Auto occupancy (persons/vehicle)

OCB = Bus Occupancy (persons/bus)

$$F_A = 1 - F_T \qquad (2)$$

$$VMT = \bar{D}T_P\left(\frac{1 - F_T}{OCA} + \frac{F_T}{OCB}\right) \qquad (1) \rightarrow (2) = (3)$$

$$\text{Baseline } VMT = VMT_o = \bar{D}T_P\left(\frac{1 - F_{T_o}}{OCA} + \frac{F_{T_o}}{OCB}\right)$$

$$\longrightarrow T_P = \frac{VMT_o}{\bar{D}\left(\frac{1 - F_{T_o}}{OCA} + \frac{F_{T_o}}{OCB}\right)} \qquad (4)$$

$$VMT = VMT_o\left(\frac{OCB(1 - F_T) + OCA(F_T)}{OCB(1 - F_{T_o}) + OCA(F_{T_o})}\right) \qquad (4) \rightarrow (3) = (5)$$

$$\%\ VMT\ \text{Reduction} = 100\left(\frac{VMT_o - VMT}{VMT_o}\right) = 100 - 100\,\frac{VMT}{VMT_o} \qquad (6)$$

$$= 100 - 100\left(\frac{OCB(1 - F_T) + OCA(F_T)}{OCB(1 - F_{T_o}) + OCA(F_{T_o})}\right) \qquad (5) \rightarrow (6) = (7)$$

Sample Calculation #1 (Cont'd)

Equation for VMT Reduction Associated with All Trips

Assume: F_{T_o} = .022 (See Reference E-1)

OCB = 15 (Best estimate)

OCA = 1.4 (See Reference E-1)

% VMT Reduction

$$= 100 - 100 \left(\frac{15(1-F_T) + 1.4\,F_T}{15(.978) + 1.4(.022)}\right)$$

$$= 100 - 100 \left(\frac{15 - 13.6F_T}{14.7}\right) = -2.18 + 92.5F_T$$

Equation for VMT Reduction Associated with Work Trips

Assume: F_{T_o} = .08 (Table 7.1)

OCB = 50 (Best estimate)

OCA = 1.1 (See Reference E-1)

Work trip VMT = 32.4% Total VMT (Table 5.4)

$$\text{\% VMT Reduction} = 0.324 \left\{100 - 100 \left(\frac{50(1-F_T) + 1.2(F_T)}{50(.92) + 1.2(.08)}\right)\right\}$$

$$= 0.324 \left\{100 - 100 \left(\frac{50-48.8\,F_T}{46.0}\right)\right\}$$

$$= -2.9 + 34.4\,F_T$$

Sample Calculation #2

VMT Reductions Due to Changes in Automobile Occupancy Rate

$$VMT = \bar{D} \left(\frac{F_A}{OCA} + \frac{F_T}{OCB} \right) T_P$$

Where:

$\bar{D}$ = Average distance (miles)

F_A = Fraction automobile passengers

F_T = Fraction transit passengers

T_P = Total passengers

OCA = Auto occupancy (persons/car)

OCB = Bus occupancy (persons/bus)

$F_A = 1 - F_T$

Assume:

1) 10% increase in travel length in a hypothetical carpool scheme, i.e., 1.1 $\overline{D}$ (2)
2) No changes in transit ridership
3) No changes in total passenger trips
4) At current levels of transit ridership, it can be assumed that $\frac{F_T}{OCB} << \frac{F_A}{OCA_o}$ (3)

Sample Calculation #2 (Cont'd)

$$\Delta VMT = VMT_o - VMT = \overline{D}T_P \left(\frac{F_A}{OCA_o} + \frac{F_T}{OCB}\right) - 1.1\ \overline{D}T_P \left(\frac{F_A}{OCA} + \frac{F_T}{OCB}\right) \qquad (2)\rightarrow(1)=(4)$$

$$= \overline{D}T_P \left(\frac{F_A}{OCA_o} - \frac{1.1\ F_A}{OCA} + \frac{F_T}{OCB} - \frac{1.1\ F_T}{OCB}\right) \qquad (5)$$

$$\simeq \overline{D}F_A T_P \left(\frac{1}{OCA_o} - \frac{1.1}{OCA}\right) \qquad (3)\rightarrow(5)=(6)$$

$$\simeq \overline{D}F_A T_P \left(\frac{OCA - 1.1\ OCA_o}{(OCA_o)(OCA)}\right) \qquad (7)$$

$$\%\ VMT\ Reduction = 100 \left(\frac{\Delta VMT}{VMT_o}\right) \qquad (8)$$

$$= 100 \left(\frac{OCA - 1.1\ OCA_o}{OCA}\right) \qquad (7)\rightarrow(8)=(9)$$

$$= 100 \left(1 - \frac{1.1\ OCA_o}{OCA}\right) \qquad (10)$$

Assume:

1) OCA_o = 1.4 (see Reference E-1)

2) Commuter VMT = 32.4% total VMT (Table 5.4)

3) OCA_o = 1.1 during commute trips (see Reference E-1)

4) 72.5% peak hour VMT is freeway related (see Appendix G, Table G-8, or Reference E-2).

Therefore, the generalized equations for % VMT reduced are:

Occupancy Rate for All Trips

$$\%\ VMT\ Reduction = 100 \left(1 - \frac{(1.1)(1.4)}{OCA}\right) = 100 \left(1 - \frac{1.54}{OCA}\right)$$

Sample Calculation #2 (Cont'd)

Occupancy Rate for Commute Trips

$$\% \text{ VMT Reduction} = (.324)(100)\left(1 - \frac{(1.1)(1.1)}{\text{OCA}}\right) = 32.4\left(1 - \frac{1.21}{\text{OCA}}\right)$$

Occupancy Rate for Freeway Commute Trips (Freeway + Non-Freeway Trip Segments)

$$\% \text{ VMT Reduction} = (.725)(32.4)\left(1 - \frac{1.21}{\text{OCA}}\right)$$

$$= 23.5\left(1 - \frac{1.21}{\text{OCA}}\right)$$

Sample Calculation #3

The Impact of SCRTD's Mini-Bus Project

Present operation

9 AM - 4 PM

1971 accumulation of auto passengers

20,700 (see Reference E-3)

1967 - 1971 growth rate (see Reference E-3)

1971 = 370,206 passengers

1967 = 345,016 passengers

difference = 25,190

$$\frac{25{,}190}{4 \text{ years}} = 6{,}125/\text{year} = 1.65\% \text{ of 1971 volume/year}$$

2 times growth rate = 3.3%/year

1977 accumulation of auto passengers

$$(20{,}700)(3.3\%)6 + 20{,}700 = 24{,}800$$

$$\text{Average trip length} = \sqrt{6 \text{ square miles}}$$

$$\simeq 2.4 \text{ miles}$$

$$\text{Potential VMT Reduction} = (24{,}800)(2.4) = 60{,}000$$

$$< 0.1\% \text{ Basin-wide VMT}$$

Sample Calculation #4

The Impact of SCRTD's San Bernardino Freeway Express Busway

1974 Patronage = 17,000 per day (see Reference E-4)

Assuming 50 percent annual growth rate:

1977 patronage = $(17,000)(1 + 0.5)^3$ = 57,800 persons per day

Assume all new passengers after the first year and 50 percent of first year passengers are also new.

Diverted patrons = 57,800 - (0.5)(17,000) = 49,300

Assume an average automobile occupancy rate of 1.3 as determined by the 1971 Downtown Los Angeles Cordon Count performed by the City of Los Angeles Traffic Department (see Reference E-3).

Diverted automobiles = 49,300/1.3 = 38,800 vehicles per day.

Assume on line stops will have one-half the patrons as will those stops with park and ride facilities and that one-half of the riders will travel to Wilshire Boulevard, the average two-way trip will be 16.4 miles long. Hence,

Reduction in vehicle miles = (38,800)(16.4) = 635,000

= 0.4 percent of total VMT

Sample Calculation #5

Joint SCRTD-OCTD Santa Ana "Park-and-Ride" Facility

Assume Voorhees Modal Split Model holds and that the following characteristics are typical for a one-way trip on the system:

Length = L = 22 miles

Income = I = 8.3¢/min. ($10,000/year)

Transit Access Time = T_a = 1 min.

Transit Wait Time = T_w = 5 min. (peak hours)
=10 min. (off-peak hours)

Transit Fare = F = 54¢ (Basic fare plus 3 additional zones)

Auto Operating Cost = A_o = $1.05 (4.8¢/mile)

Auto Parking Cost = A_p = 50¢

Auto Terminal Cost = A_t = 5 min. (peak hour)
= 2 min. (off peak hour)

Since an exclusive bus lane on this freeway is not possible because of several geometric bottlenecks, further assume that the transit riding time and automobile riding time (T_r and A_r) are equal.

According to the Voorhees Model (E-5) marginal utility, U, is equal to

$$2.5(T_a + T_u - A_t) + T_r - A_r + \frac{F - (A_o + A_p)}{0.25\ I}$$

Substituting the assumed values into the equation for this particular trip, U = -45 and -25 during peak hours and off-peak hours, respectively. Consequently, a 30 percent commuting ridership and 8 percent off peak transit ridership can be expected.

Sample Calculation #5 (Cont'd)

1971 Average daily vehicle volume $^{(E-6)}$ = 120,000

Assume a 2 percent per year growth rate*

1977 Average daily vehicle volume = 135,000

Assume peak hour traffic averages 7 percent of total traffic.

1977 peak time vehicle volumes = 4 (.07)(135,000) = 38,000

Optimistically assume all of transit ridership is diverted from automobiles

Diverted vehicles = .30(38,000) + .08(97,000) = 19,000 per day

VMT reduction = 19,000 x 44 miles

= 836,000 vehicle miles

= 0.5 percent of total VMT

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*During 1968 to 1971, volumes on the freeway dropped due to completion of new freeways in the area. The trend is expected to reverse.

Sample Calculation #6

VMT by the Los Angeles Yellow Cab Company

1967: 0.1% of all trips by taxi(E-1)

Average taxi trip length in San Francisco = 4.75 mi.

Average taxi trip length in Oakland = 3.0 mi.

Average private auto trip in Los Angeles = 7.6 mi.(E-2)

Therefore, a reasonable assumption is that the average Los Angeles taxi trip distance is less than the average private auto trip. This implies that passengers using the Los Angeles Yellow Cab Company account for less than 0.1% of the Basin's VMT.

Somehow divert passengers over to this system -- 0.2% of the Basin's VMT could be reduced if Yellow Cab Company doubled their service with two occupants in each additional trip. Therefore, it seems unlikely that any more than a fraction of one percent of the VMT could be reduced by an expanded taxi service.

Sample Calculation #6a

Impact of the "Ideal" Transit System (Very Optimistic)

$$U = 2.5(T_a+T_w) + T_r - (2.5A_t+A_r) + \frac{F-(A_o+A_p)}{0.25\ I}$$

Where

T_a+T_w = 5 minutes

$T_r = A_r$ (transit as fast as auto)

A_t = 2 minutes

F = 0¢ (free transit)

A_o+A_p = 36¢ (7.6 miles @ 4.8¢/mile)

I = 8.3¢/minute ($10,000/year)

Trip Length = 7.6 miles

U = -10

→ % Transit Ridership $\simeq$15
→ % VMT Reduction $\simeq$10

Sample Calculation #6b

Impact of "Reasonably Improved" Transit

$$U = 2.5(T_a+T_w) + T_r - (2.5A_t+A_r) + \frac{F-(A_o+A_p)}{0.25\ I}$$

Where

T_a+T_w = 10 minutes

T_r = 25 minutes (18 MPH average)

A_t = 2 minutes

A_r = 16 minutes (28 MPH average)

F = 30¢ (basic fare)

A_o+A_p = 36¢ (7.6 miles @ 4.8¢/mile)

I = 8.3¢/minute ($10,000/year)

Trip Length = 7.6 miles

U = 64

→ % Transit Ridership $\simeq$5%
→ % VMT Reduction $\simeq$3%

Sample Calculation #7

The Impact of Prohibiting Automobile Usage

Example: Creating an Auto Free Zone in the Los Angeles CBD

Assume that through traffic, which is primarily on the freeway network, cannot be diverted. Therefore, only trips with trip ends in the CBD will be eliminated.

From the 1971 Downtown Los Angeles Cordon Count (E-3)

1971 -- Peak Accumulation = 123,853 persons

1971 Commuters -- Accumulation @ 9 a.m. = 97,267 persons

1971 Non-Commuters (difference) = 26,586 persons

Projections to 1977:

Both commuter and non-commuter historical counts in the Downtown CBD indicate negative growth rates; however, this trend is expected to reverse with the current redevelopment program.

Employment is expected to increase by 100,000 in ten years in the CBD(E-7); hence, commuter accumulation can be expected to increase at the rate of 10,000 per year. Assuming that the non-commuter growth will be less than twice the growth rate of travel across the cordon boundaries which grew at the rate of 1.65 percent per year,(E-3) the non-commuter travel will be estimated by linear projections at 3.3 percent per year.

1977 Commuters -- Accumulation @ 9 A.M. = 97,000 + 6 (10,000)
= 157,000 persons

1977 Non-Commuters = $(26,586)(1 + .033)^6$
= 29,000 persons

Sample Calculation #7 (Cont'd)

Assuming that 1971 modal split rates will not change substantially by 1977, 55.6 percent of the commuter accumulation and 57.1 percent of the non-commuter accumulation will be brought to the CBD by automobile.(E-3)

1977 Commuter - Vehicle Accumulation = 87,000 vehicles
1977 Non-Commuter - Vehicle Accumulation = 17,000 vehicles

From Table 5.4, the average trip length for a commute trip is approximately 10.5 miles and the weighted average of non-commute trips is 6.7 miles.

As defined in the Downtown Los Angeles 1971 Cordon Count, the CBD is slightly larger than one square mile; hence, the average trip length within the CBD is probably not more than one mile in length.

Consequently, if automobile use in the CBD were prohibited, one could expect the following VMT reductions. Assume that no diversion to mass transit will take place.

Vehicle Mile Reduced = 104,000 vehicles x 1 mile
= 104,000 vehicle miles

Further, assume that all of the trips with a destination inside of the CBD will be made entirely by mass transit or by foot.

Vehicle Miles Reduced:
= 87,000 vehicles x 10.5 miles + 17,000 vehicles x 6.7 miles
= 1,027,000 vehicle miles <1% VMT Basin-wide

Sample Calculation #8

The Impact of a Four-Day Work Week

The following assumptions were made in the analysis:

- As a result of changing to a four-day week, an individual's mid-week (Tuesday, Wednesday, Thursday) travel pattern will be replaced by an additional Saturday-Sunday type travel pattern.
- The extra weekend day will be an average of the typical Saturday-Sunday travel pattern. For a fixed income, the number of shopping trips will not increase substantially and will likely redistribute between the Saturday and new weedkend day. On the other hand, the new weekend day will not be as restful as the present Sunday pattern.
- To be socially acceptable, the new non-working day will be either a Friday or Monday. To preserve the present significance of Sunday, Friday was chosen as the substitutional day.
- Certain employment types cannot be adapted to a four-day week and hence will be unaffected. Generally, the unaffected workers will be in service-related jobs which are responsive to the non-work demands of others.

Table 7.8 shows average travel data for various trip purposes as determined by the System Development Corporation report entitled A Survey of Average Driving Patterns in the Los Angeles Urban Area, and by the 1967 Los Angeles Regional Transportation Study -- Origin-Destination Study. The trip lengths for the various trip types listed in Table 5.4 were applied to the trip frequency data shown in Table 7.8 to arrive at a weekly total of 33,741 vehicle miles for the sample population.

Sample Calculation #8 (Cont'd)

From Table 7.8 we calculate the following:

- Average (unweighted) of Tuesday, Wednesday, Thursday vehicle miles = 5247
- Average (unweighted) of Saturday, Sunday vehicle mi. = 3633

difference = 1614

$$\text{\% VMT Reduction} = \frac{1614}{5247} = 4.8\%$$

Hence the substitution of the average weekend day for the average weekday resulted in a 4.8 percent reduction in weekly vehicle miles traveled (VMT).

1980 Employment Projections by the Standard Industrial Classifications (SIC) were obtained from the Southern California Association of Governments (SCAG). From the projections, it was determined that approximately 70 percent of the employment force could be put on a four-day work week; hence, a potential reduction of 3.4 percent of the weekly vehicle miles.

To estimate the impact on daily VMT, it is assumed that the weekly reduction can be evenly spread over six days of the week, excluding Sunday. Thus, the impact of a four-day week is:

$$\text{\% Daily VMT Reduction} = \frac{3.4\%}{6} \simeq 0.6\%$$

Sample Calculation #9

Impact of Exclusive Bus-Carpool Lane

Assumptions:

	Source
1) Trip length = 10.1 miles	See Appendix G, Table G-8. (Trip to freeway is excluded.)
2) 20 minute travel time advantage for users of the lane	San Bernardino Busway will have 18 minute advantage; Shirley Highway Busway has 30 minute advantage.
3) Values of Voorhees parameters	
T_a = 2 minutes	Assumed
T_w = 3 minutes	5 minute headway for correct bus
F = 46¢	Basic 30¢ fare + 2 zones
A_o = 48¢ (or 78¢)	4.8¢ per mile (+3¢ per mile "tax")
A_p = 2.5¢	Assumed
A_t = 2 minutes	See Reference E-5
T_r-A_r = 20 minutes	20 minute time advantage
I = 8.3¢/minute	$10,000 per year

$$U = 2.5\ (T_a+T_w) + T_r - (2.5A_t+A_r) + \frac{F - (A_o+A_p)}{0.25\ I}$$

U = -15 (-29 with 3¢ per mile "tax")

Based on the above assumptions and Figure 7.2, the estimated transit patronage is approximately 15 percent without the tax and 20 percent with the tax.

Sample Calculation #9 (Cont'd)

$$\% \text{ VMT Reduction} = 100-100 \left\{ \frac{OCB(1-F_T) + OCA(F_T)}{OCB(1-F_{T_o}) + OCA(F_{T_o})} \right\} \text{ (Eq. (7), Sample Calculation \#1)}$$

The percentage of total commute VMT which is travelled on the freeway system in the Basin is approximately 17 percent (see Appendix G, Table G-8); therefore,

$$\% \text{ VMT Reduction} = .17 \left\{ 100-100 \left[\frac{OCB(1-F_T) + OCA(F_T)}{OCB(1-F_{T_o}) + OCA(F_{T_o})} \right] \right\}$$

Assume:

1) OCB = 50 persons per bus
2) OCA = 1.1 persons per car
3) F_{T_o} = negligible on freeways presently
4) F_T = .15 (.20 with "tax")

% VMT Reduction = 2.5 (or 3.2 with "tax")

To achieve an occupancy of 1.5

Assume:

1) During commute periods, average volume per lane of traffic of 1500 vehicles per hour
2) Carpool is three or more people per automobile
3) Negligible carpooling on the freeway presently
4) Eight lane freeway (four in each direction)
5) Capacity of freeway lanes is 1800 vehicles per hour
6) No diversion to transit
7) Total person trips on freeway is constant

Sample Calculation #9 (Cont'd)

Let N = Number of cars in carpool lane (three persons per car) when all other lanes are at capacity and the resultant average automobile occupancy is 1.5 persons per vehicle.

Then
$$\frac{(3)(1800 \text{ veh./ln-hr})(1.1 \text{ persons/veh.}) + N(3 \text{ persons/veh.})}{(3)(1800) + N \text{ veh./ln-hr}} = 1.5$$

$\rightarrow N = 1440$ veh./ln-hr

Persons diverting to carpools = 1440 x 3 = 4320

Total number of person trips = (3)(1800)(1.1) + (1440)(3) = 11,340

% of freeway commuters shifting to car pools = $\frac{4,320}{11,340}$ = 38%

Impact of Shifts in Carpools

Assume occupancy can be increased to 1.5 persons per vehicle.

From Sample Calculation #2 for commute periods periods,

$$\% \text{ VMT Reduction} = 32.4 \left(1- \frac{1.21}{OCA}\right)$$

This strategy impacts 72.5 percent of the commute VMT (see Appendix G, Table G-8).

$$\% \text{ VMT Reduction} = .725(32.4)(1- \frac{1.21}{OCA})$$

$$= 23.5 \ (1- \frac{1.21}{1.5})$$

$$= 4.4\%$$

Sample Calculation #10

Limitation of Second, Third...Family Cars

From Appendix F, the corresponding vehicle ownerships as a percentage of surveyed car owners is:

	Number of cars owned			
	1	2	3	4+
Percent of car owners	32	45	18	5

The cumulative frequency of car ownership is:

	1	2	3	4+
Percent of car owners who own at least N cars	100	68	23	5

(Number of cars = N)

From vehicle mileage data in Appendix F (Question 9 of Consumer Mail Panel Questionnaire).

	Annual Mileage	Percent owning at least N cars	Sample Normalized VMT
Car Number 1	12,300	100	1,230,000
Car Number 2	9,600	68	652,000
Car Number 3	9,400	23	216,000
Car Number 4	4,700	5	24,000
TOTAL			2,122,000

Percentage of VMT by Car Number 1 = 1,230,000/2,122,000 = 58 percent

Percentage of VMT by "extra cars" = 100 - 58 = 42 percent of respondent annual vehicle mileage

Sample Calculation #11

Required Bus Acquisitions

Table 5.5 illustrates the peaking nature of traffic in the South Coast Basin during commute hours. The present accepted practice in estimating transit requirements is based on the assumption that if the commute demands are met, demands during other times of the day will also be met.

Commute Demand

Assumptions:

- person trips will remain unchanged in number and length
- average occupancy of bus will be 40 persons per bus during commute times
- a bus will be able to complete three round trips during commute times (2 to 3 hours)
- morning demand = evening demand

$$\text{Home to work person trips} = \frac{(\text{H-W VMT})(\text{H-W Occupancy})}{(\text{H-W Average Distance})(1.0 - \text{H-W Transit Ridership})}$$

$$= \frac{(.324)(168 \times 10^6)(1.14)}{(10.5)(0.92)} = 6{,}409{,}000$$

$$\text{Demand} = (\text{H-W person trips}/2)(\text{Transit ridership}) = 3{,}204{,}000 \times \text{Transit Ridership}$$

$$\text{Supply of buses} = \frac{\text{Demand}}{\text{Capacity per bus}} = \frac{3{,}204{,}000}{(40)(3)} = 26{,}700 \times \text{Transit Ridership}$$

Sample Calculation #11 (Cont'd)

Estimated Current Supply

From Table 9.1, 1971 Supply = 1838 buses

Additional Expected Buses

OCTD = 241 buses

5%* Current Supply = 92 buses

TOTAL = 2171 buses

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*SCRTD indicated that it keeps a 10 percent reserve which could immediately be added to the supply. Assume that averaged over the Basin a 5 percent reserve is available.

References

E-1 California Division of Highways, LARTS Base Year Report - 1967 Origin - Destination Survey, December, 1971.

E-2 Kearin, D. H., and Lamoureaux, R. L., A Survey of Average Driving Patterns in the Los Angeles Urban Area, System Development Corporation Technical Memo (TM(L)-4119/000/01), February 1969.

E-3 City of Los Angeles Traffic Department, 1971 Downtown Los Angeles Cordon Count, March 1972.

E-4 Southern California Rapid Transit District, California Division of Highways - District 7, San Bernardino Freeway Express Busway Project - Facts at a Glance, July 29, 1972.

E-5 Alan M. Voorhees and Associates, Inc., Los Angeles Mode Choice Development Study, February, 1972.

E-6 California Division of Highways, 1971 Traffic Volumes on the California State Highway System, 1971.

E-7 Board of the Greater Los Angeles Urban Coalition, Summary Proposed Study of Public Benefits from Increasing Commuter Vehicle Occupancy by 1975 in the Los Angeles Basin, unpublished paper, June 1972.

APPENDIX F

PUBLIC OPINION SURVEYS LOS ANGELES METROPOLITAN REGION

I. Los Angeles Attitude Survey

Presented on the pages which follow are results of a questionnaire distributed to a small sample of households in the greater Los Angeles area (see Table F-1). The survey was conducted with the assistance of a professional market research group* which maintains standing panels of households in each major metropolitan area of the U.S.; each panel represents a broad cross-section of households in the given area. The following table indicates some characteristics of the Los Angeles panel.

Table B-1 CAR OWNERSHIP OF SAMPLE

	0-Car	1-Car	2-Car	3-Car	4+-Car	Total
Respondents	5	60	85	34	9	193
Percentage	2.6	31.1	44.0	17.6	4.7	100

Table B-2 ANNUAL FAMILY INCOME OF SAMPLE

	≤$4000	$4000-$8000	$8,000-$10,000	$10,000-$15,000	$15,000+	Total
Respondents	13	40	27	50	55	193
Percentage	6.7	20.7	14.0	30.1	28.5	100

The results of the survey are presented in Table F-2.

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*Consumer Mail Panels, Chicago, Illinois

Significant insights to public attitudes which can be gleaned from the survey are as follows:

- Nearly 96 percent of the respondents feel that air pollution is a problem in the Los Angeles area; 81 per cent feel that the problem is "serious" to "very serious". The respondents did not feel that the problem was significantly worse or better nationwide -- 98 per cent indicated there was a problem nationwide and 89 per cent feel that the problem is serious to very serious (see question 10).

- Los Angeles residents are generally supportive of retrofit programs for pre-1975 vehicles which would cost about $50 per vehicle. Some 66 per cent of the respondents indicated they would support such a program and an additional 15 per cent indicated they were not strongly opposed to such a program. If the retrofit to pre-1975 vehicles were to cost $200 per vehicle only some 33 per cent would support it. One might infer that low cost retrofits would be highly acceptable but higher priced requirements (e.g., catalytic converters) would not be highly palatable (see question 2).

- Some 80 per cent of the respondents favor an inspection/maintenance program. Another 8 per cent are not strongly opposed to such a program. On the average the respondents indicated they would be willing to pay nearly $8.00 for the annual inspection, significantly above the actual estimated costs for inspection programs under consideration. Over 41 per cent of the respondents feel the inspection should be conducted at state-operated inspection centers while some 39 per cent feel local service stations or garages should be able to perform the inspection (see question 3).

- Reaction to all types of travel restriction controls is generally negative. Among the restrictive controls, exclusive bus and car pool lanes followed by restrictions on "non-essential" auto travel during times of high pollution and a parking and traffic ban in the downtown CBD were the least objectionable. All three of these programs are easily perceived by a respondent as not applying to his particular situation, and hence having the least impact on his personal travel patterns. A very high vehicle registration fee was overwhelmingly rated the least acceptable program with gasoline rationing rated the second most unacceptable program (see question 4).

- Response to transit related questions generally reflects the current low utilization of the existing transit system. Over 93 per cent of the husbands, 84 per cent of the wives, and 87 per cent of the children over 16 years of age reported that they never use public transportation. The most commonly mentioned reason for using transit was the unavailability of an automobile or driver's license while flexibility and faster travel speed were most commonly mentioned as reasons for using the automobile.

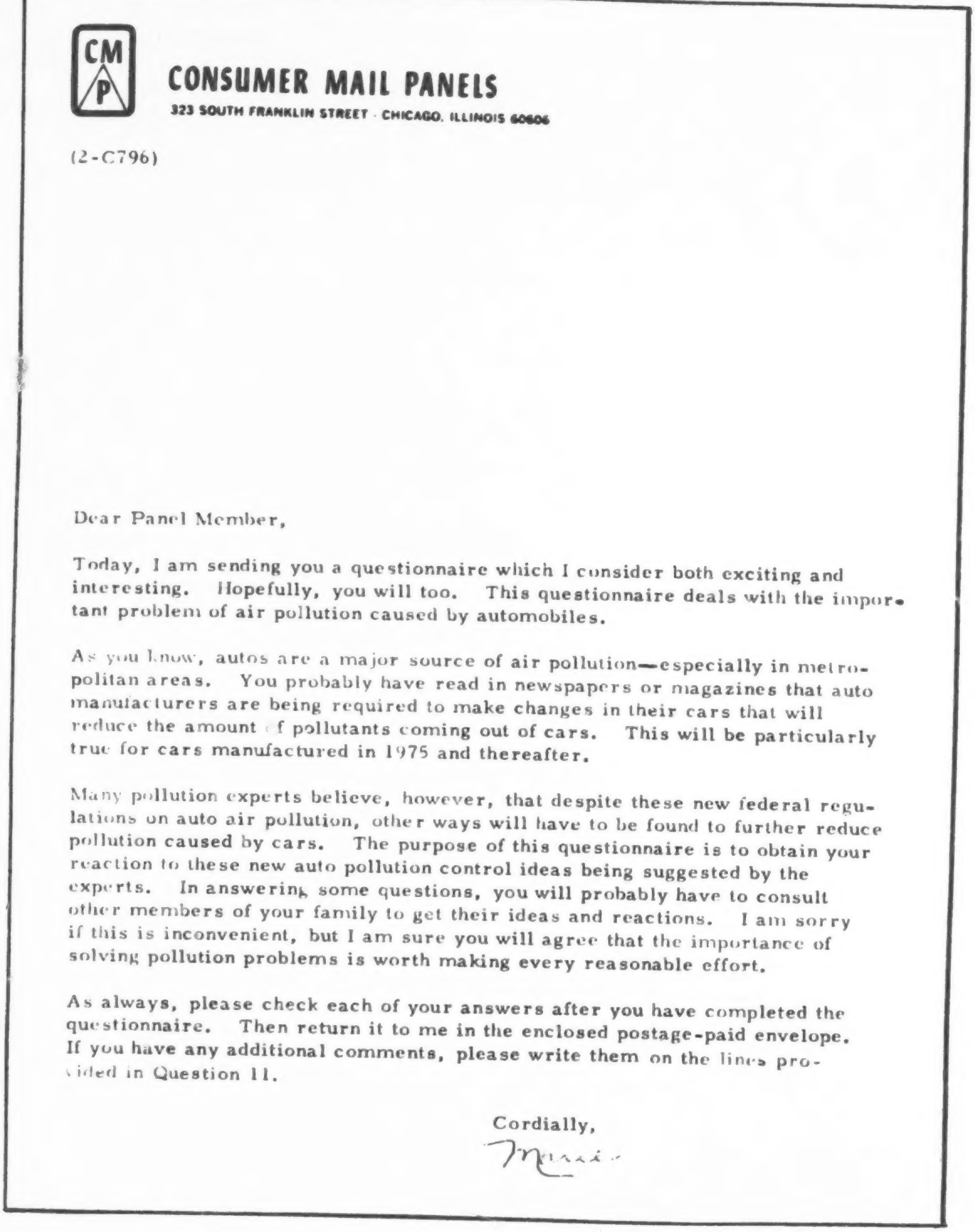
- It was generally recognized that the automobile costs more, but lower transit fares were not rated as being an effective strategy to increase transit ridership. Faster, more frequent, and more conveniently located service were the strategies rated highest in potential effectiveness. The responses indicated that achievement of significant increases in the level of transit utilization may require a major capital and operating commitment to a more extensive level of service than that currently provided rather than cosmetic improvements such as cleaner buses, air conditioning, bus stop benches and shelters, security, and the like (see question 5).

- Forty per cent of the respondents indicated interest in car pooling for work commute trips while only four per cent indicated that they are already in a car pool. On the other hand, however, 84 per cent indicated it would be difficult to organize new or join existing car pools (see question 6).

- Some 67 per cent of the respondents favor staggered work hours as a means of reducing traffic congestion while slightly over 20 per cent oppose the concept (see question 8).

- Only 15 percent of the respondents would consider disposal of one family car if better public transit were available. Another 16 per cent indicated they might consider disposing of an automobile.

TABLE F-1
LOS ANGELES METROPOLITAN AREA ATTITUDE SURVEY



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CONSUMER MAIL PANELS
323 SOUTH FRANKLIN STREET · CHICAGO, ILLINOIS 60606

(2-C796)

Dear Panel Member,

Today, I am sending you a questionnaire which I consider both exciting and interesting. Hopefully, you will too. This questionnaire deals with the important problem of air pollution caused by automobiles.

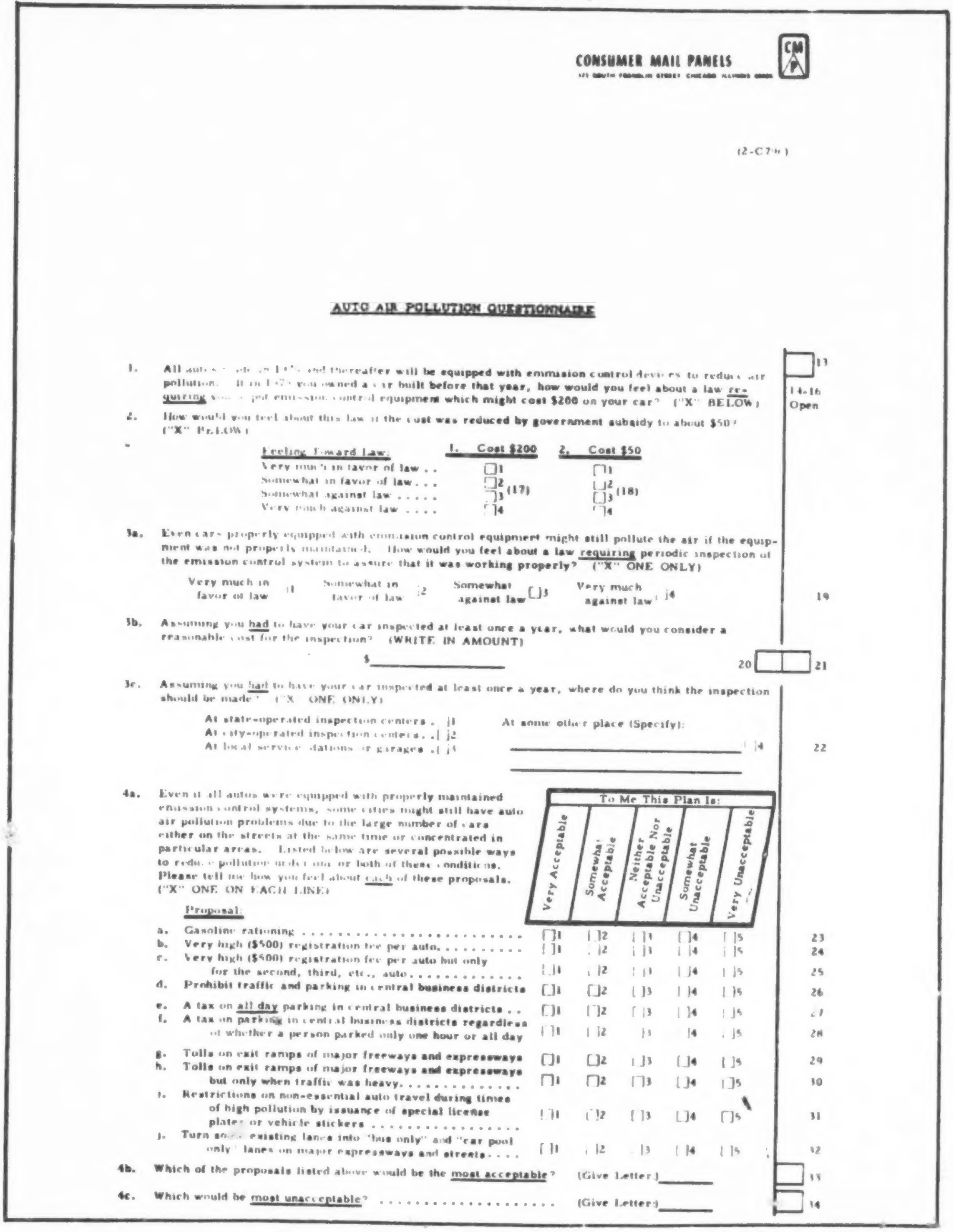
As you know, autos are a major source of air pollution—especially in metropolitan areas. You probably have read in newspapers or magazines that auto manufacturers are being required to make changes in their cars that will reduce the amount of pollutants coming out of cars. This will be particularly true for cars manufactured in 1975 and thereafter.

Many pollution experts believe, however, that despite these new federal regulations on auto air pollution, other ways will have to be found to further reduce pollution caused by cars. The purpose of this questionnaire is to obtain your reaction to these new auto pollution control ideas being suggested by the experts. In answering some questions, you will probably have to consult other members of your family to get their ideas and reactions. I am sorry if this is inconvenient, but I am sure you will agree that the importance of solving pollution problems is worth making every reasonable effort.

As always, please check each of your answers after you have completed the questionnaire. Then return it to me in the enclosed postage-paid envelope. If you have any additional comments, please write them on the lines provided in Question 11.

Cordially,

TABLE F-1 (CONT'D)



CONSUMER MAIL PANELS

(2-C7[illegible])

AUTO AIR POLLUTION QUESTIONNAIRE

☐ 13

14-16 Open

1. All autos made in [illegible] and thereafter will be equipped with emmission control devices to reduce air pollution. If in [illegible] you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law . .	☐1	☐1
Somewhat in favor of law . . .	☐2	☐2
Somewhat against law	☐3	☐3
Very much against law	☐4	☐4
	(17)	(18)

3a. Even cars properly equipped with emission control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law ☐1 Somewhat in favor of law ☐2 Somewhat against law ☐3 Very much against law ☐4 — 19

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$__________ — 20 ☐☐ 21

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers . ☐1
At city-operated inspection centers . . ☐2
At local service stations or garages . ☐3
At some other place (Specify): __________ ☐4 — 22

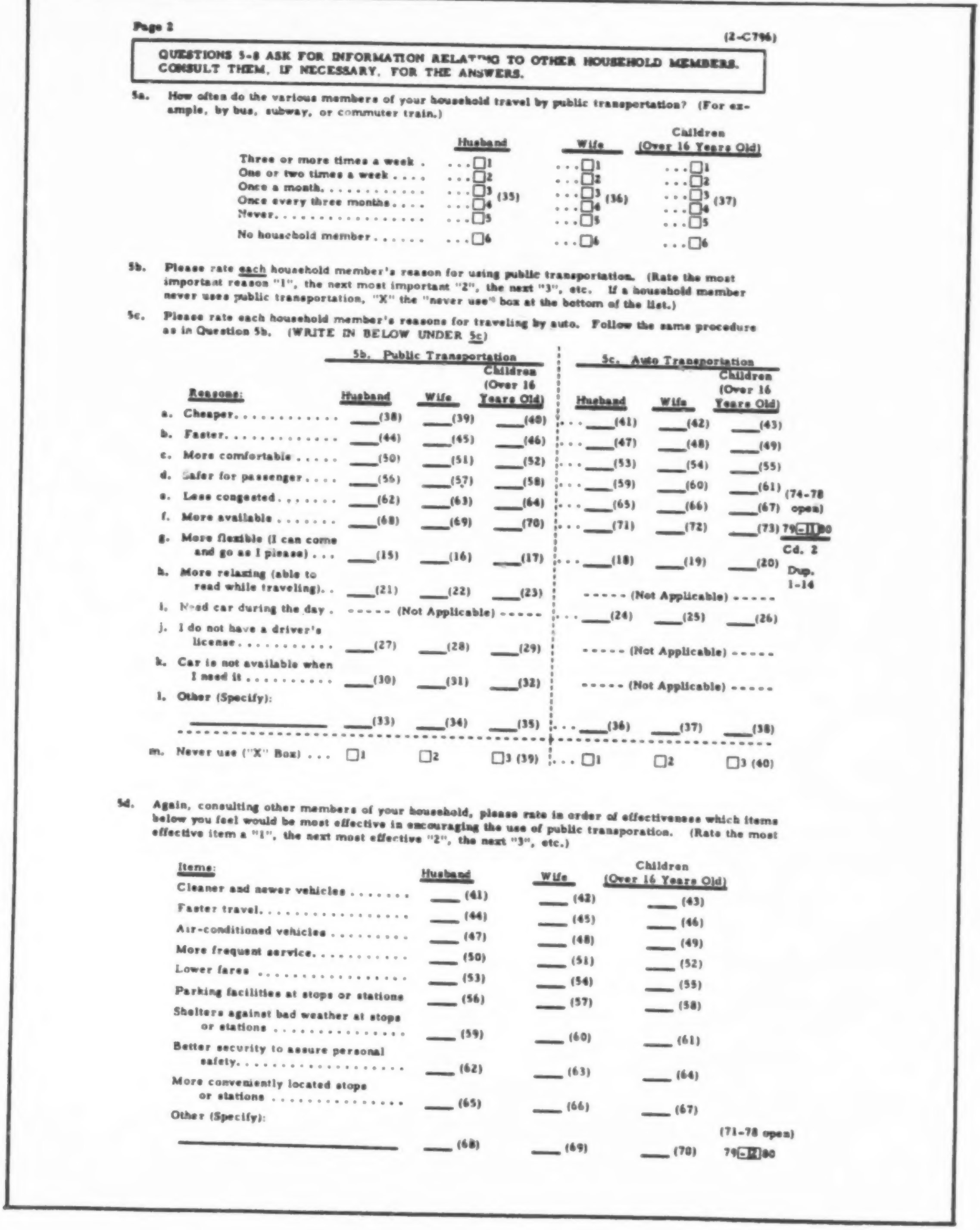
4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

Proposal:	To Me This Plan Is: Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable	
a. Gasoline rationing	☐1	☐2	☐3	☐4	☐5	23
b. Very high ($500) registration fee per auto.	☐1	☐2	☐3	☐4	☐5	24
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto.	☐1	☐2	☐3	☐4	☐5	25
d. Prohibit traffic and parking in central business districts	☐1	☐2	☐3	☐4	☐5	26
e. A tax on all day parking in central business districts . .	☐1	☐2	☐3	☐4	☐5	27
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	☐1	☐2	☐3	☐4	☐5	28
g. Tolls on exit ramps of major freeways and expressways	☐1	☐2	☐3	☐4	☐5	29
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy.	☐1	☐2	☐3	☐4	☐5	30
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	☐1	☐2	☐3	☐4	☐5	31
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	☐1	☐2	☐3	☐4	☐5	32

4b. Which of the proposals listed above would be the most acceptable? (Give Letter) ______ ☐ 33

4c. Which would be most unacceptable? . . . . (Give Letter) ______ ☐ 34

TABLE F-1 (CONT'D)



Page 2

(2-C796)

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week	☐1	☐1	☐1
One or two times a week	☐2	☐2	☐2
Once a month	☐3 (35)	☐3 (36)	☐3 (37)
Once every three months	☐4	☐4	☐4
Never	☐5	☐5	☐5
No household member	☐6	☐6	☐6

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportation		
Reasons:	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old)
a. Cheaper	___(38)	___(39)	___(40)	___(41)	___(42)	___(43)
b. Faster	___(44)	___(45)	___(46)	___(47)	___(48)	___(49)
c. More comfortable	___(50)	___(51)	___(52)	___(53)	___(54)	___(55)
d. Safer for passenger	___(56)	___(57)	___(58)	___(59)	___(60)	___(61)
e. Less congested	___(62)	___(63)	___(64)	___(65)	___(66)	___(67)
f. More available	___(68)	___(69)	___(70)	___(71)	___(72)	___(73)
g. More flexible (I can come and go as I please)	___(15)	___(16)	___(17)	___(18)	___(19)	___(20)
h. More relaxing (able to read while traveling)	___(21)	___(22)	___(23)	----- (Not Applicable) -----		
i. Need car during the day	----- (Not Applicable) -----			___(24)	___(25)	___(26)
j. I do not have a driver's license	___(27)	___(28)	___(29)	----- (Not Applicable) -----		
k. Car is not available when I need it	___(30)	___(31)	___(32)	----- (Not Applicable) -----		
l. Other (Specify): ________	___(33)	___(34)	___(35)	___(36)	___(37)	___(38)
m. Never use ("X" Box)	☐1	☐2	☐3 (39)	☐1	☐2	☐3 (40)

(74-78 open)

79 -1 80

Cd. 2

Dup. 1-14

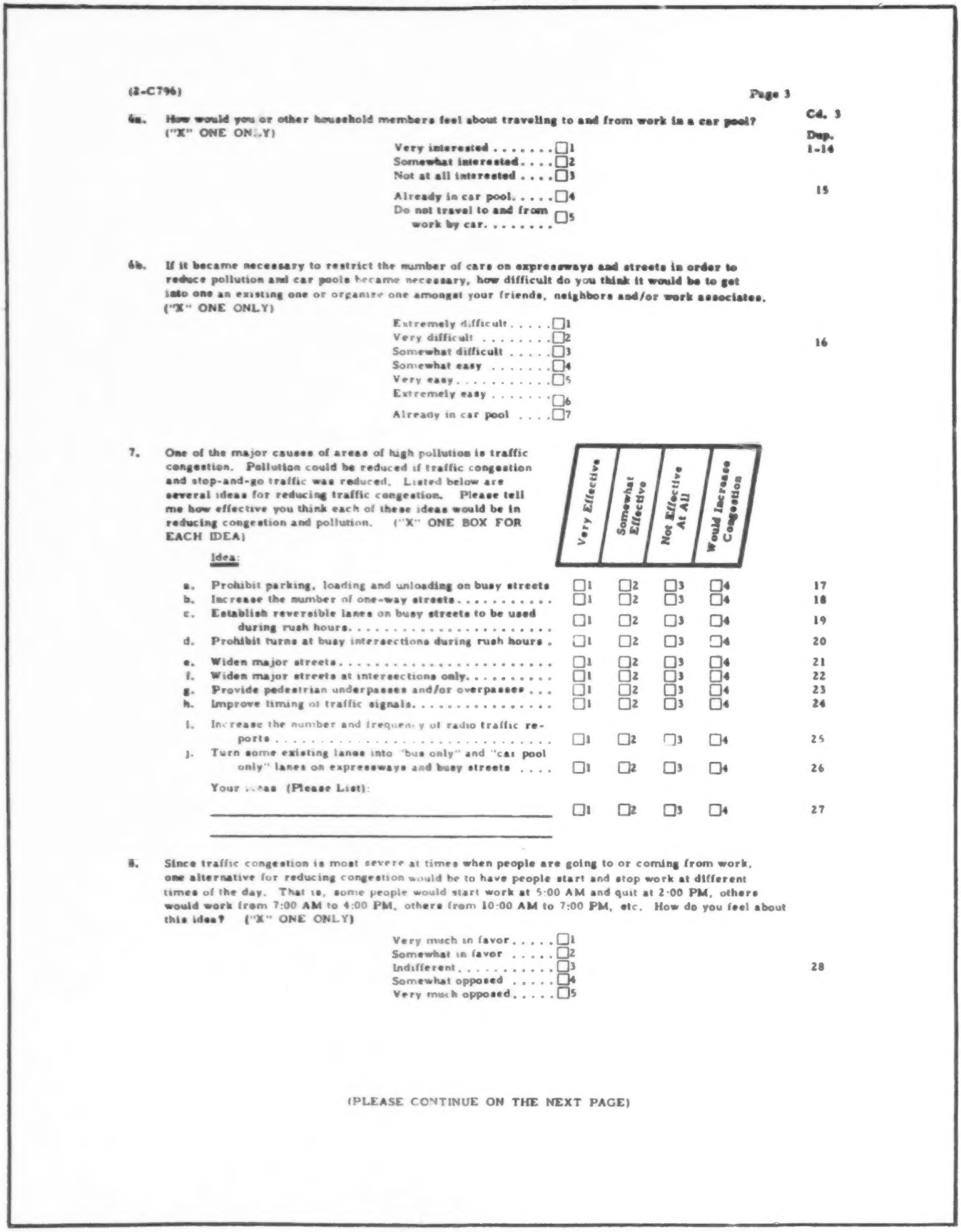
5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)
Cleaner and newer vehicles	___ (41)	___ (42)	___ (43)
Faster travel	___ (44)	___ (45)	___ (46)
Air-conditioned vehicles	___ (47)	___ (48)	___ (49)
More frequent service	___ (50)	___ (51)	___ (52)
Lower fares	___ (53)	___ (54)	___ (55)
Parking facilities at stops or stations	___ (56)	___ (57)	___ (58)
Shelters against bad weather at stops or stations	___ (59)	___ (60)	___ (61)
Better security to assure personal safety	___ (62)	___ (63)	___ (64)
More conveniently located stops or stations	___ (65)	___ (66)	___ (67)
Other (Specify): ________	___ (68)	___ (69)	___ (70)

(71-78 open)

79 -2 80

TABLE F-1 (CONT'D)



(2-C796) Page 3

Cd. 3
Dup.
1-14

6a. How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY)

Very interested . . . . ☐1
Somewhat interested . . . . ☐2
Not at all interested . . . . ☐3
Already in car pool. . . . . ☐4 15
Do not travel to and from work by car. . . . . ☐5

6b. If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)

Extremely difficult . . . . . ☐1
Very difficult . . . . ☐2 16
Somewhat difficult . . . . . ☐3
Somewhat easy . . . . ☐4
Very easy. . . . . ☐5
Extremely easy . . . . ☐6
Already in car pool . . . . ☐7

7. One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)

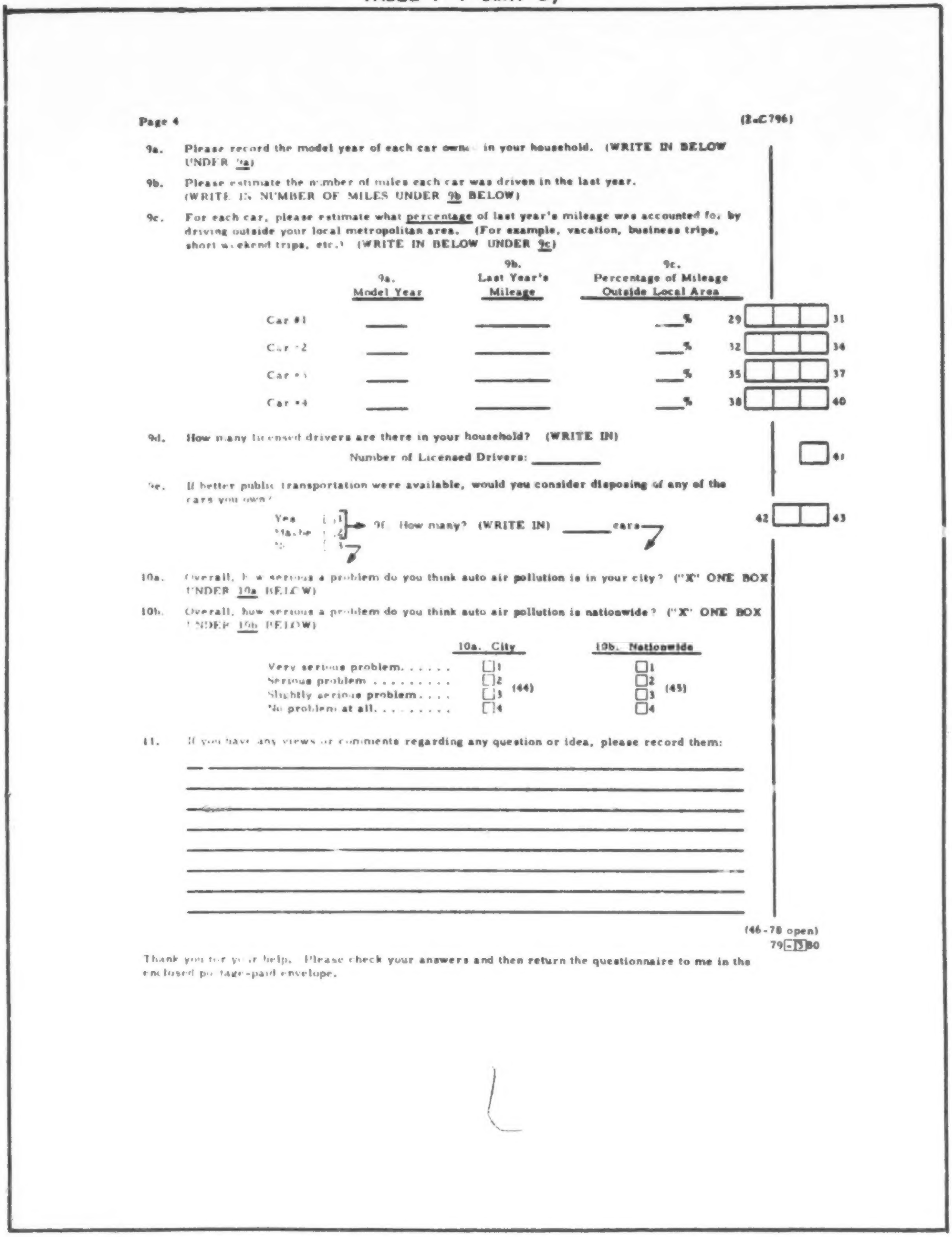
Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion	
a. Prohibit parking, loading and unloading on busy streets	☐1	☐2	☐3	☐4	17
b. Increase the number of one-way streets.	☐1	☐2	☐3	☐4	18
c. Establish reversible lanes on busy streets to be used during rush hours.	☐1	☐2	☐3	☐4	19
d. Prohibit turns at busy intersections during rush hours .	☐1	☐2	☐3	☐4	20
e. Widen major streets.	☐1	☐2	☐3	☐4	21
f. Widen major streets at intersections only.	☐1	☐2	☐3	☐4	22
g. Provide pedestrian underpasses and/or overpasses . . .	☐1	☐2	☐3	☐4	23
h. Improve timing of traffic signals.	☐1	☐2	☐3	☐4	24
i. Increase the number and frequency of radio traffic reports	☐1	☐2	☐3	☐4	25
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	☐1	☐2	☐3	☐4	26
Your ideas (Please List): ____________________________ ____________________________	☐1	☐2	☐3	☐4	27

8. Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)

Very much in favor . . . . . ☐1
Somewhat in favor . . . . . ☐2
Indifferent. . . . . ☐3 28
Somewhat opposed . . . . . ☐4
Very much opposed . . . . . ☐5

(PLEASE CONTINUE ON THE NEXT PAGE)

TABLE F-1 CONT'D)



Page 4 (2-C796)

9a. Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)

9b. Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)

9c. For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area	
Car #1	____	________	___%	29 ☐☐☐ 31
Car #2	____	________	___%	32 ☐☐☐ 34
Car #3	____	________	___%	35 ☐☐☐ 37
Car #4	____	________	___%	38 ☐☐☐ 40

9d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: ________ ☐ 41

9e. If better public transportation were available, would you consider disposing of any of the cars you own?

Yes ☐1 → 9f. How many? (WRITE IN) _____ cars → 42 ☐☐ 43
Maybe ☐2
No ☐3

10a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)

10b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)

	10a. City	10b. Nationwide
Very serious problem.	☐1	☐1
Serious problem	☐2 (44)	☐2 (45)
Slightly serious problem. . . .	☐3	☐3
No problem at all.	☐4	☐4

11. If you have any views or comments regarding any question or idea, please record them:

____
____
____
____
____
____
____
____

(46-78 open)
79 3 80

Thank you for your help. Please check your answers and then return the questionnaire to me in the enclosed postage-paid envelope.

TABLE F-2

RESULTS OF THE LOS ANGELES ATTITUDE SURVEY

1. All autos made in 1975 and thereafter will be equipped with emmision control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law..	10.5%	42.9%
Somewhat in favor of law...	22.2%	23.4%
Somewhat against law......	13.1%	14.7%
Very much against law.....	54.2%	19.0%

3a. Even cars properly equipped with emmision control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law	Somewhat in favor of law	Somewhat against law	Very much against law
48.4%	31.6%	8.4%	11.6%

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$ 7.87

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers.....	41.3%
At city-operated inspection centers......	14.3%
At local service stations or garages.....	38.6%
At some other place (Specify):	5.8%

TABLE F-2 (CONT'D)

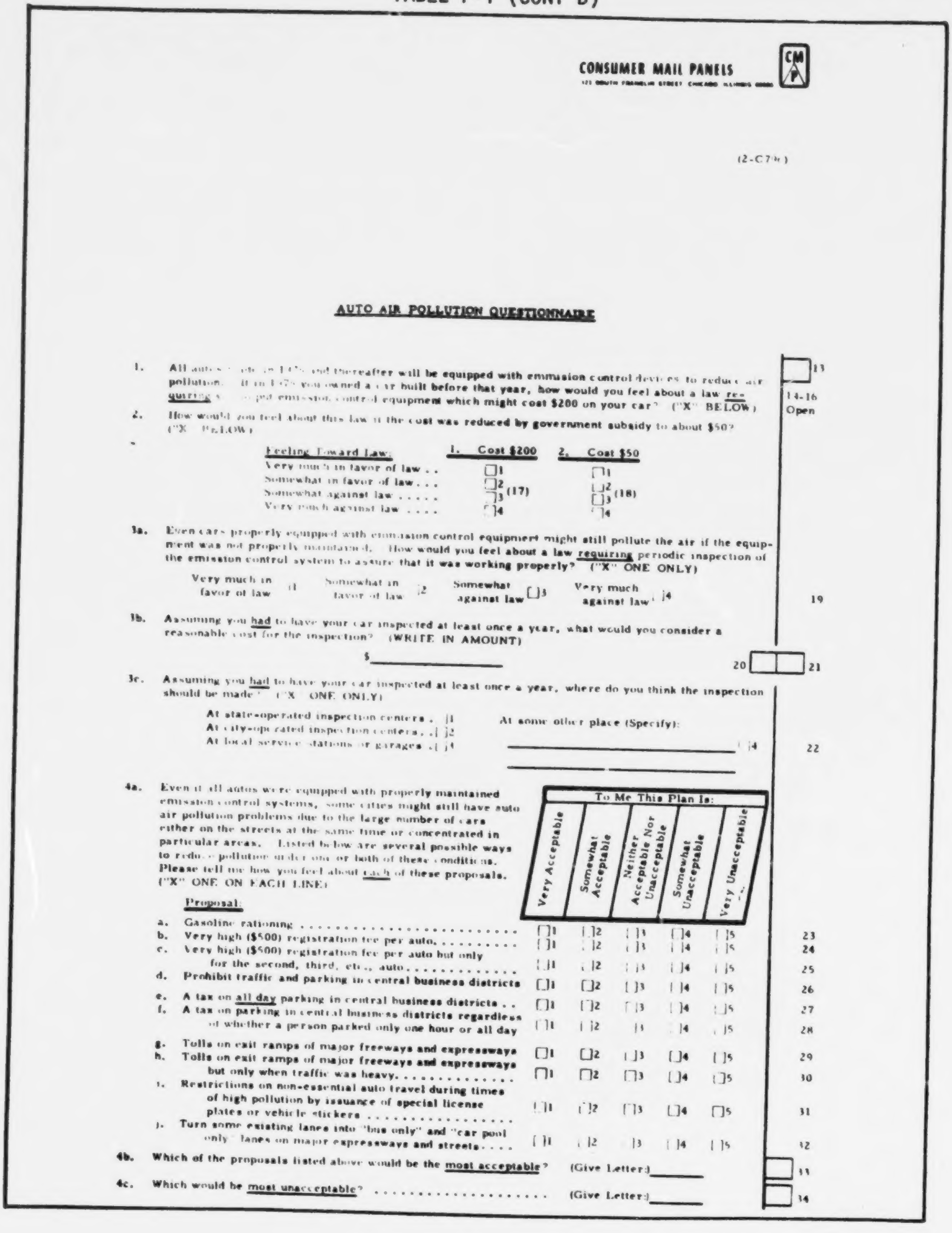
4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

	To Me This Plan Is:				
	Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable
Proposal	+2	+1	0	0	-1
a. Gasonline rationing	2.1%	5.9%	6.4%	12.8%	72.9%
b. Very high ($500) registration fee per auto	0.5%	2.7%	2.7%	2.1%	92.0%
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto	4.4%	7.1%	2.7%	11.5%	74.3%
d. Prohibit traffic and parking in central business districts	16.1%	29.0%	8.6%	18.3%	28.0%
e. A tax on all day parking in central business districts	12.8%	16.5%	17.6%	14.9%	38.3%
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	5.4%	11.3%	14.5%	16.1%	52.7%
g. Tolls on exit ramps of major Freeways and expressways	3.7%	4.8%	8.0%	11.8%	71.7%
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy	2.2%	8.2%	8.2%	16.5%	64.8%
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	15.1%	21.0%	9.7%	18.3%	36.0%
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	35.3%	29.9%	10.2%	10.2%	14.4%

4b. Which of the proposals listed above would be the most acceptable? (Give Letter:) J - 48.1%
I - 19.9%

4c. Which would be most unacceptable? (Give Letter:) B - 56.1%
A - 29.6%

TABLE F-1 (CONT'D)



CONSUMER MAIL PANELS
[illegible]

(2-C7[illegible])

AUTO AIR POLLUTION QUESTIONNAIRE

1. All autos made in [illegible] and thereafter will be equipped with emmission control devices to reduce air pollution. If in [illegible] you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law . .	☐1	☐1
Somewhat in favor of law . . .	☐2 (17)	☐2 (18)
Somewhat against law	☐3	☐3
Very much against law	☐4	☐4

13

14-16 Open

3a. Even cars properly equipped with emission control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law ☐1 Somewhat in favor of law ☐2 Somewhat against law ☐3 Very much against law ☐4 19

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$__________ 20 ☐☐ 21

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers . ☐1
At city-operated inspection centers . . ☐2
At local service stations or garages . ☐3
At some other place (Specify): __________ ☐4 22

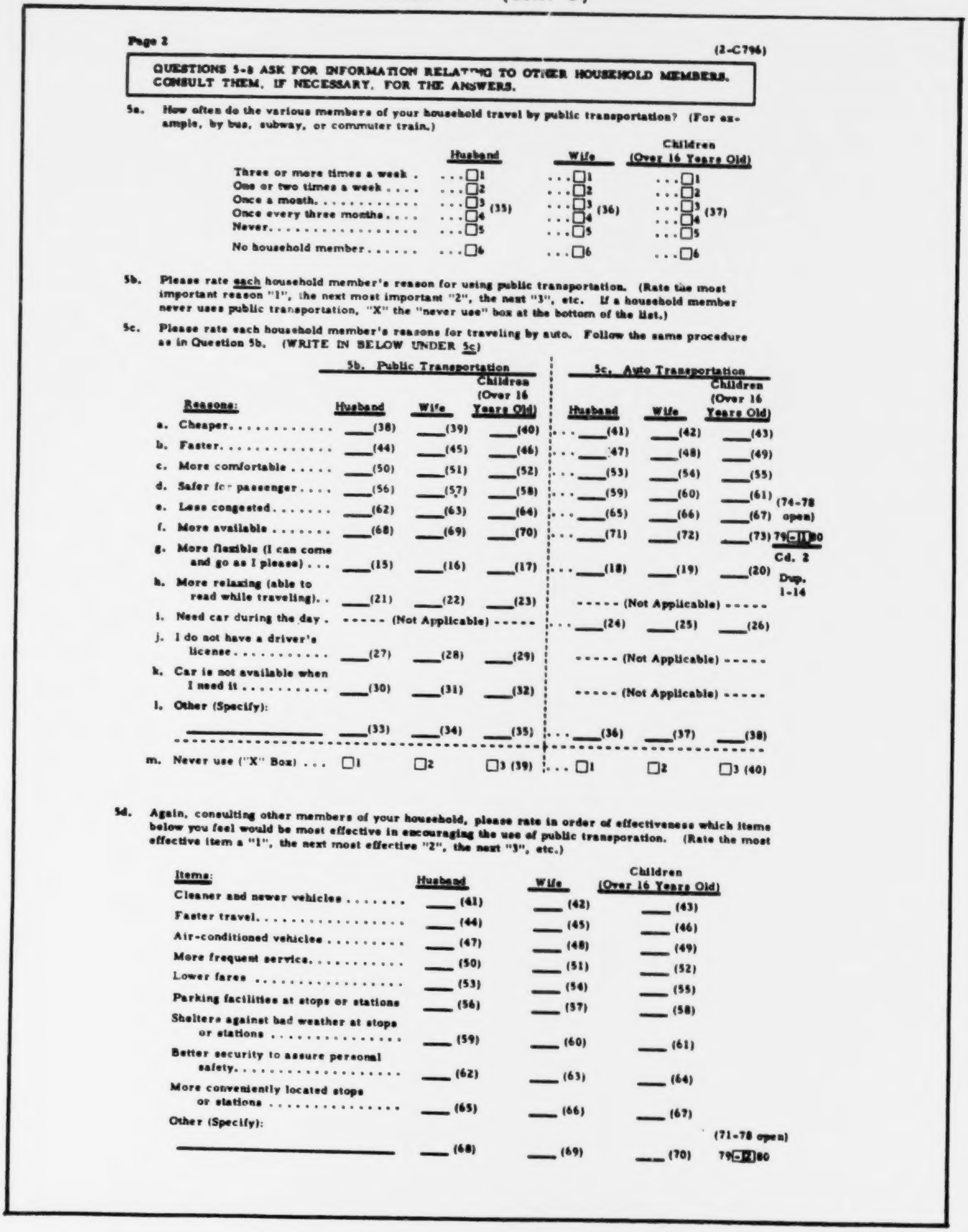
4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

Proposal:	To Me This Plan Is: Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable	
a. Gasoline rationing	☐1	☐2	☐3	☐4	☐5	23
b. Very high ($500) registration fee per auto.	☐1	☐2	☐3	☐4	☐5	24
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto.	☐1	☐2	☐3	☐4	☐5	25
d. Prohibit traffic and parking in central business districts	☐1	☐2	☐3	☐4	☐5	26
e. A tax on all day parking in central business districts . .	☐1	☐2	☐3	☐4	☐5	27
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	☐1	☐2	☐3	☐4	☐5	28
g. Tolls on exit ramps of major freeways and expressways	☐1	☐2	☐3	☐4	☐5	29
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy.	☐1	☐2	☐3	☐4	☐5	30
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	☐1	☐2	☐3	☐4	☐5	31
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	☐1	☐2	☐3	☐4	☐5	32

4b. Which of the proposals listed above would be the most acceptable? (Give Letter:)______ ☐ 33

4c. Which would be most unacceptable? . . . . (Give Letter:)______ ☐ 34

TABLE F-1 (CONT'D)



Page 2

(2-C796)

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week	☐1	☐1	☐1
One or two times a week	☐2	☐2	☐2
Once a month	☐3 (35)	☐3 (36)	☐3 (37)
Once every three months	☐4	☐4	☐4
Never	☐5	☐5	☐5
No household member	☐6	☐6	☐6

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

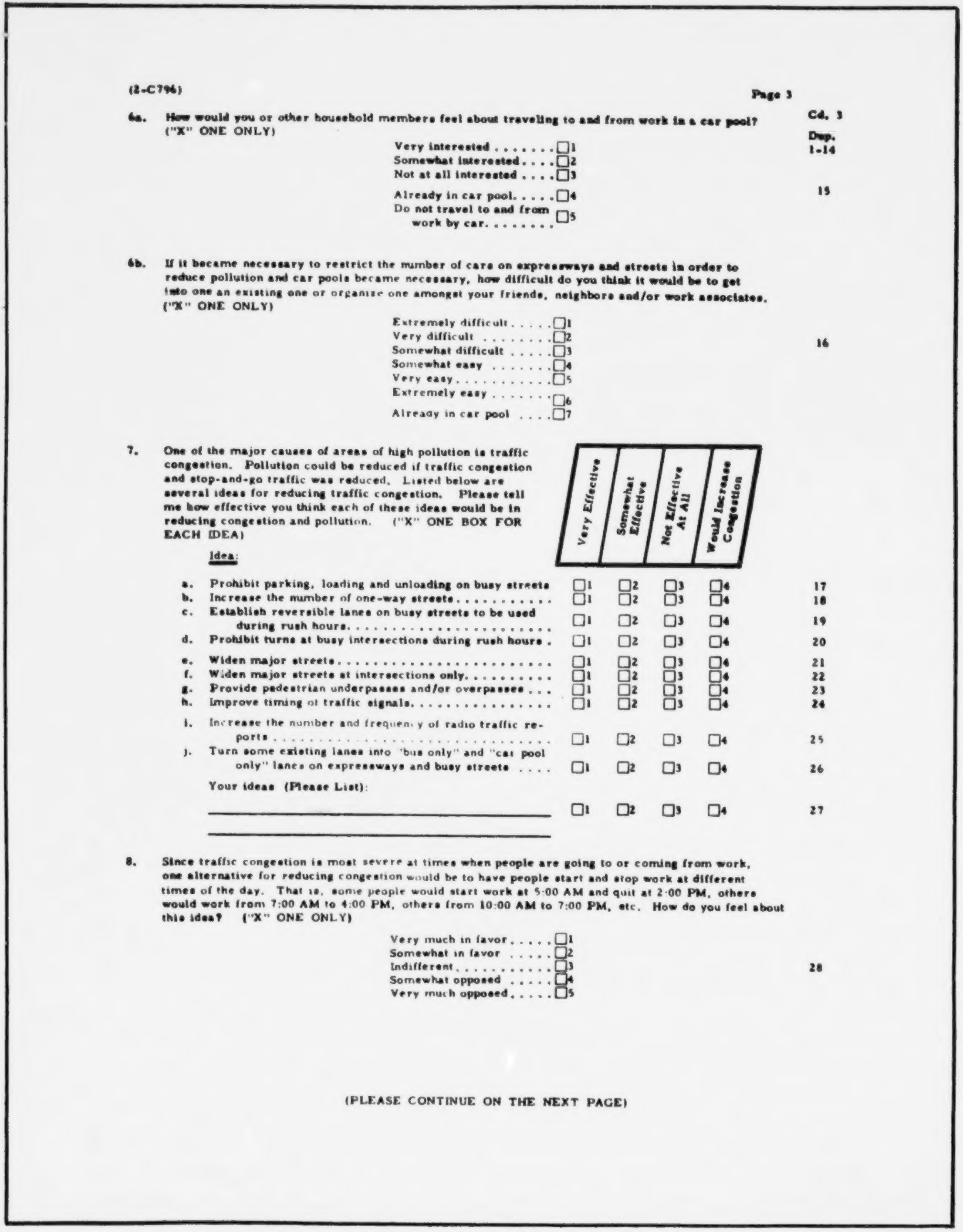
5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportation			
Reasons:	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old)	
a. Cheaper	____(38)	____(39)	____(40)	____(41)	____(42)	____(43)	
b. Faster	____(44)	____(45)	____(46)	____(47)	____(48)	____(49)	
c. More comfortable	____(50)	____(51)	____(52)	____(53)	____(54)	____(55)	
d. Safer for passenger	____(56)	____(57)	____(58)	____(59)	____(60)	____(61)	(74-78 open)
e. Less congested	____(62)	____(63)	____(64)	____(65)	____(66)	____(67)	
f. More available	____(68)	____(69)	____(70)	____(71)	____(72)	____(73)	79 -1 80
g. More flexible (I can come and go as I please)	____(15)	____(16)	____(17)	____(18)	____(19)	____(20)	Cd. 2
h. More relaxing (able to read while traveling)	____(21)	____(22)	____(23)	----- (Not Applicable) -----			Dup. 1-14
i. Need car during the day	----- (Not Applicable) -----			____(24)	____(25)	____(26)	
j. I do not have a driver's license	____(27)	____(28)	____(29)	----- (Not Applicable) -----			
k. Car is not available when I need it	____(30)	____(31)	____(32)	----- (Not Applicable) -----			
l. Other (Specify): ________	____(33)	____(34)	____(35)	____(36)	____(37)	____(38)	
m. Never use ("X" Box)	☐1	☐2	☐3 (39)	☐1	☐2	☐3 (40)	

5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)	
Cleaner and newer vehicles	____ (41)	____ (42)	____ (43)	
Faster travel	____ (44)	____ (45)	____ (46)	
Air-conditioned vehicles	____ (47)	____ (48)	____ (49)	
More frequent service	____ (50)	____ (51)	____ (52)	
Lower fares	____ (53)	____ (54)	____ (55)	
Parking facilities at stops or stations	____ (56)	____ (57)	____ (58)	
Shelters against bad weather at stops or stations	____ (59)	____ (60)	____ (61)	
Better security to assure personal safety	____ (62)	____ (63)	____ (64)	
More conveniently located stops or stations	____ (65)	____ (66)	____ (67)	
Other (Specify): ________	____ (68)	____ (69)	____ (70)	(71-78 open) 79 -2 80

TABLE F-1 (CONT'D)



(2-C796) Page 3

6a. How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY) Cd. 3 Dup. 1-14

Very interested . . . . ☐1
Somewhat interested . . . . ☐2
Not at all interested . . . . ☐3
Already in car pool. . . . . ☐4 15
Do not travel to and from work by car. . . . . ☐5

6b. If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)

Extremely difficult . . . . . ☐1
Very difficult . . . . ☐2
Somewhat difficult . . . . . ☐3 16
Somewhat easy . . . . ☐4
Very easy. . . . . ☐5
Extremely easy . . . . ☐6
Already in car pool . . . . ☐7

7. One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)

Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion	
a. Prohibit parking, loading and unloading on busy streets	☐1	☐2	☐3	☐4	17
b. Increase the number of one-way streets	☐1	☐2	☐3	☐4	18
c. Establish reversible lanes on busy streets to be used during rush hours.	☐1	☐2	☐3	☐4	19
d. Prohibit turns at busy intersections during rush hours .	☐1	☐2	☐3	☐4	20
e. Widen major streets.	☐1	☐2	☐3	☐4	21
f. Widen major streets at intersections only.	☐1	☐2	☐3	☐4	22
g. Provide pedestrian underpasses and/or overpasses . . .	☐1	☐2	☐3	☐4	23
h. Improve timing of traffic signals.	☐1	☐2	☐3	☐4	24
i. Increase the number and frequency of radio traffic reports	☐1	☐2	☐3	☐4	25
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	☐1	☐2	☐3	☐4	26
Your ideas (Please List): ______________________ ______________________	☐1	☐2	☐3	☐4	27

8. Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)

Very much in favor . . . . . ☐1
Somewhat in favor . . . . . ☐2
Indifferent. . . . . ☐3 28
Somewhat opposed . . . . . ☐4
Very much opposed . . . . . ☐5

(PLEASE CONTINUE ON THE NEXT PAGE)

TABLE F-1 CONT'D)

Page 4 (2-C796)

9a. Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)

9b. Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)

9c. For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area	
Car #1	____	________	___%	29 ☐☐☐ 31
Car #2	____	________	___%	32 ☐☐☐ 34
Car #3	____	________	___%	35 ☐☐☐ 37
Car #4	____	________	___%	38 ☐☐☐ 40

9d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: ________ ☐ 41

9e. If better public transportation were available, would you consider disposing of any of the cars you own?

Yes ☐1 → 9f. How many? (WRITE IN) ______ cars
Maybe ☐2
No ☐3

42 ☐☐ 43

10a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)

10b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)

	10a. City	10b. Nationwide
Very serious problem.	☐1	☐1
Serious problem	☐2 (44)	☐2 (45)
Slightly serious problem	☐3	☐3
No problem at all.	☐4	☐4

11. If you have any views or comments regarding any question or idea, please record them:

____
____
____
____
____
____
____
____

(46-78 open)
79 ☐-☐3 80

Thank you for your help. Please check your answers and then return the questionnaire to me in the enclosed postage-paid envelope.

TABLE F-2

RESULTS OF THE LOS ANGELES ATTITUDE SURVEY

1. All autos made in 1975 and thereafter will be equipped with emmision control devices to reduce air pollution. If in 1975 you owned a car built before that year, how would you feel about a law requiring you to put emission control equipment which might cost $200 on your car? ("X" BELOW)

2. How would you feel about this law if the cost was reduced by government subsidy to about $50? ("X" BELOW)

Feeling Toward Law:	1. Cost $200	2. Cost $50
Very much in favor of law. .	10.5%	42.9%
Somewhat in favor of law. . .	22.2%	23.4%
Somewhat against law.	13.1%	14.7%
Very much against law.	54.2%	19.0%

3a. Even cars properly equipped with emmision control equipment might still pollute the air if the equipment was not properly maintained. How would you feel about a law requiring periodic inspection of the emission control system to assure that it was working properly? ("X" ONE ONLY)

Very much in favor of law	Somewhat in favor of law	Somewhat against law	Very much against law
48.4%	31.6%	8.4%	11.6%

3b. Assuming you had to have your car inspected at least once a year, what would you consider a reasonable cost for the inspection? (WRITE IN AMOUNT)

$ 7.87

3c. Assuming you had to have your car inspected at least once a year, where do you think the inspection should be made? ("X" ONE ONLY)

At state-operated inspection centers.	41.3%
At city-operated inspection centers.	14.3%
At local service stations or garages	38.6%
At some other place (Specify):	5.8%

TABLE F-2 (CONT'D)

4a. Even if all autos were equipped with properly maintained emission control systems, some cities might still have auto air pollution problems due to the large number of cars either on the streets at the same time or concentrated in particular areas. Listed below are several possible ways to reduce pollution under one or both of these conditions. Please tell me how you feel about each of these proposals. ("X" ONE ON EACH LINE)

	To Me This Plan Is:				
	Very Acceptable	Somewhat Acceptable	Neither Acceptable Nor Unacceptable	Somewhat Unacceptable	Very Unacceptable
Proposal	+2	+1	0	0	-1
a. Gasonline rationing	2.1%	5.9%	6.4%	12.8%	72.9%
b. Very high ($500) registration fee per auto	0.5%	2.7%	2.7%	2.1%	92.0%
c. Very high ($500) registration fee per auto but only for the second, third, etc., auto	4.4%	7.1%	2.7%	11.5%	74.3%
d. Prohibit traffic and parking in central business districts	16.1%	29.0%	8.6%	18.3%	28.0%
e. A tax on all day parking in central business districts	12.8%	16.5%	17.6%	14.9%	38.3%
f. A tax on parking in central business districts regardless of whether a person parked only one hour or all day	5.4%	11.3%	14.5%	16.1%	52.7%
g. Tolls on exit ramps of major Freeways and expressways	3.7%	4.8%	8.0%	11.8%	71.7%
h. Tolls on exit ramps of major freeways and expressways but only when traffic was heavy	2.2%	8.2%	8.2%	16.5%	64.8%
i. Restrictions on non-essential auto travel during times of high pollution by issuance of special license plates or vehicle stickers	15.1%	21.0%	9.7%	18.3%	36.0%
j. Turn some existing lanes into "bus only" and "car pool only" lanes on major expressways and streets	35.3%	29.9%	10.2%	10.2%	14.4%

4b. Which of the proposals listed above would be the most acceptable? (Give Letter:) J - 48.1%

I - 19.9%

4c. Which would be most unacceptable? .... (Give Letter:) B - 56.1%

A - 29.6%

TABLE F-2 (CONT'D)

QUESTIONS 5-8 ASK FOR INFORMATION RELATING TO OTHER HOUSEHOLD MEMBERS. CONSULT THEM, IF NECESSARY, FOR THE ANSWERS.

5a. How often do the various members of your household travel by public transportation? (For example, by bus, subway, or commuter train.)

	Husband	Wife	Children (Over 16 Years Old)
Three or more times a week .	0.6%	2.7%	4.7%
One or two times a week.	2.3%	1.6%	0.9%
Once a month.	1.1%	2.7%	----
Once every three months	1.7%	8.5%	2.8%
Never	86.3%	84.6%	55.1%
No household member	8.0%	-----	36.4%

5b. Please rate each household member's reason for using public transportation. (Rate the most important reason "1", the next most important "2", the next "3", etc. If a household member never uses public transportation, "X" the "never use" box at the bottom of the list.)

5c. Please rate each household member's reasons for traveling by auto. Follow the same procedure as in Question 5b. (WRITE IN BELOW UNDER 5c)

	5b. Public Transportation			5c. Auto Transportation		
Reasons	Husband	Wife	Children (Over 16 Years Old)	Husband	Wife	Children (Over 16 Years Old)
a. Cheaper				6	5	5
b. Faster				1	3	3
c. More comfortable . .				5	5	5
d. Safer for passenger.				8	7	7
e. Less congested.				6	7	7
f. More available	SEE COMMENTS			1	1	1
g. More flexible (I can come and go as I please).				3	1	1

TABLE F-2 (CONT'D)

h. More relaxing (able to read while traveling)........	---- Not Applicable ----		
i. Need car during the day.............	3	3	4
j. I do not have a driver's license..	---- Not Applicable ----		
k. Car is not available when I need it....	---- Not Applicable ----		
l. Other (Specify): ________________	---- See Comments ----		
m. Never use ("X" Box)			

5d. Again, consulting other members of your household, please rate in order of effectiveness which items below you feel would be most effective in encouraging the use of public transporation. (Rate the most effective item a "1", the next most effective "2", the next "3", etc.)

Items:	Husband	Wife	Children (Over 16 Years Old)
Cleaner and newer vehicles..	6	6	7
Faster travel	2	3	2
Air-conditioned vehicles	6	6	5
More frequent service	1	1	1
Lower fares	4	3	4
Parking facilities at stops or stations	5	5	5

TABLE F-2 (CONT'D)

Shelters against bad weather at stops or stations	6	6	9
Better security to assure personal safety...........	6	6	7
More conveniently located stops and stations	2	2	2
Other (Specify):			

6a. **How would you or other household members feel about traveling to and from work in a car pool? ("X" ONE ONLY)**

Very interested	18.1%
Somewhat interested........	22.3%
Not at all interested	43.6%
Already in car pool.........	4.3%
Do not travel to and from work by car..............	11.7%

6b. **If it became necessary to restrict the number of cars on expressways and streets in order to reduce pollution and car pools became necessary, how difficult do you think it would be to get into one an existing one or organize one amongst your friends, neighbors and/or work associates. ("X" ONE ONLY)**

Extremely difficult	37.2%
Very difficult	24.0%
Somewhat difficult..........	22.4%
Somewhat easy.............	8.2%
Very easy	2.2%
Extremely easy	3.8%
Already in car pool.........	2.2%

TABLE F-2 (CONT'D)

7. **One of the major causes of areas of high pollution is traffic congestion. Pollution could be reduced if traffic congestion and stop-and-go traffic was reduced. Listed below are several ideas for reducing traffic congestion. Please tell me how effective you think each of these ideas would be in reducing congestion and pollution. ("X" ONE BOX FOR EACH IDEA)**

Idea:	Very Effective	Somewhat Effective	Not Effective At All	Would Increase Congestion
	+2	+1	0	C
a. Prohibit parking, loading and unloading on busy streets	43.8%	45.5%	10.2%	0.6%
b. Increase the number of one-way streets	28.7%	44.8%	19.3%	7.2%
c. Establish reversible lanes on busy streets to be used during rush hours	31.1%	37.9%	16.4%	14.7%
d. Prohibit turns at busy intersections during rush hours	49.2	36.2%	9.6%	5.1%
e. Widen major streets	46.1%	33.9%	17.2%	2.8%
f. Widen major streets at intersections only	8.1%	39.9%	33.5%	18.5%
g. Provide pedestrian underpasses and/or overpasses	39.7%	42.0%	15.5%	2.9%
h. Improve timing of traffic signals	62.1%	35.0%	2.3%	0.6%
i. Increase the number and frequency of radio traffic reports	19.9%	50.6%	26.1%	3.4%
j. Turn some existing lanes into "bus only" and "car pool only" lanes on expressways and busy streets	35.9%	42.5%	17.7%	3.9%

-1

Your ideas (Please List):

8. **Since traffic congestion is most severe at times when people are going to or coming from work, one alternative for reducing congestion would be to have people start and stop work at different times of the day. That is, some people would start work at 5:00 AM and quit at 2:00 PM, others would work from 7:00 AM to 4:00 PM, others from 10:00 AM to 7:00 PM, etc. How do you feel about this idea? ("X" ONE ONLY)**

Very much in favor	34.9%
Somewhat in favor	32.3%
Indifferent	12.7%
Somewhat opposed	10.6%
Very much opposed	9.5%

TABLE F-2 (CONT'D)

9a. Please record the model year of each car owned in your household. (WRITE IN BELOW UNDER 9a)

9b. Please estimate the number of miles each car was driven in the last year. (WRITE IN NUMBER OF MILES UNDER 9b BELOW)

9c. For each car, please estimate what percentage of last year's mileage was accounted for by driving outside your local metropolitan area. (For example, vacation, business trips, short weekend trips, etc.) (WRITE IN BELOW UNDER 9c)

	9a. Model Year	9b. Last Year's Mileage	9c. Percentage of Mileage Outside Local Area
Car #1	1968	12296	27
Car #2	1967	9593	24
Car #3	1967	9366	29
Car #4	1966	4666	3

9d. How many licensed drivers are there in your household? (WRITE IN)

Number of Licensed Drivers: 2.0

9e. If better public transportation were available, would you consider disposing of any of the cars you own?

Yes	14.7%
Maybe	15.8%
No	69.6%

9f. How many? (WRITE IN) 1.04 cars

TABLE F-2 (CONT'D)

10a. Overall, how serious a problem do you think auto air pollution is in your city? ("X" ONE BOX UNDER 10a BELOW)

10b. Overall, how serious a problem do you think auto air pollution is nationwide? ("X" ONE BOX UNDER 10b BELOW)

	10a. City	10b. Nationwide
Very serious problem	55.3%	40.8%
Serious problem	26.1%	48.4%
Slightly serious problem ...	14.4%	9.2%
No problem at all	4.3%	1.6%

11. If you have any views or comments regarding any question or idea, please record them:

II. Additional Los Angeles Attitude Surveys

Our research has uncovered two other recent and germain attitude surveys in the Los Angeles area. These publications are respectively entitled "Public Concern and Beliefs About Air Pollution in California: A Statewide Survey", published in Project Clean Air Research Reports, Volume 3, University of California, 1970 and Mass Transit in Los Angeles: An Analysis, published by Clarmont College, 1972

The first survey sought to document the public concerns and beliefs about air pollution. Table F-3 summarizes come of the results below:

- Some 25 percent of the Southern California respondents voluntarily replied "air pollution" in response to the question, "Is there anything in this area that particularly bothers you?" Sixty-six per cent listed air pollution as one of the three "most serious" problems. Only six percent did not think air pollution was a serious problem.
- In response to the questions, "Do you think air pollution or smog has reached a point where it is a danger for normal, healthy people?" 73 per cent of the Southern California respondents replied affirmatively and an additional 14 per cent said "maybe".
- The public generally believes that auto exhaust and industry are principal causes for air pollution. 81 per cent mentioned automobiles and 71 per cent mentioned industry (respondents were allowed to answer more than once).
- When asked if they believe anyone is doing anything about air pollution 35 percent responded negatively while the remainder of the Southern California sample did not seem to be in consensus about who is doing the work. Likewise there is no general agreement over who should be responsible for insuring clean air.
- The respondents were generally in favor of a mandatory annual vehicle inspection program, with 71 per cent indicating they would support such a program. This tends to reinforce the results of the previously discussed Consumer Mail Panel survey in which 80 per cent responded favorably to such a program.

The second survey was conducted in the city of West Covina, a suburb 17 miles east of Downtown Los Angeles. The survey tended to indicate some of commuter attitudes towards mass transit. Table F-4 lists the responses to the questions which are summarized below:

- The respondents generally did not think that there was a need for more freeways in Southern California. Only 27 percent thought there was a need.

- Only one-half of the respondents (50.4 per cent) felt they would benefit from a mass transit system while 85 per cent felt "the people of Southern California" would benefit indicating the attitude that mass transit is all right...for everyone else. Forty-six per cent indicated they presently could use a bus to get to work, but less than two per cent indicated they did not drive to work.

- Reductions in air pollution and congestion were the most commonly mentioned benefits that could be derived from a mass transit system.

- It is interesting to note that more than 57 per cent of the respondents would like to see a Monorail for the mass transit system while only seven percent would like to see a bus system. Similar low responses were made in favor of other conventional types of transit (e.g. ground train, subway, freeways).

- When asked about financing of mass transit respondents favored federal grants and indicated strong resistance to a property tax. Eighty per cent of the respondents indicated they would not vote for a transit bond proposal. There was indications of mild support for a sales tax and an additional gas tax.

- Respondents, on the average, indicated that they felt the commute fare should be less than 98 cents, and they would be "willing" to pay around 70 cents per trip.

TABLE F-3

RESULTS OF PROJECT CLEAN AIR PUBLIC ATTITUDES SURVEY

Is there anything about living in this area that particularly bothers you? (If Yes) What is it that particularly bothers you? Anything else?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs. college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Air Pollution/Smog	14	17	20	24	25	29	16	10	11	9
Other General Problems	33	39	42	48	43	42	44	36	40	32
Personal Problems	18	17	23	21	20	20	21	18	23	14
Nothing	50	45	37	38	39	39	41	49	44	54
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-3 (CONT'D)

Here is a card listing some problems that people talk about. I would like you to look through these and select the three you think are most serious these days.

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Crime and Violence in the Streets	70	65	57	59	61	60	62	66	64	68
Air Pollution	50	59	63	70	66	68	60	50	53	47
Property Taxes	35	40	36	22	34	34	34	34	34	33
Race Relations	23	29	32	44	30	27	38	33	32	34
Unemployment	33	29	29	17	26	26	25	31	26	35
Quality of Local Schools	22	23	19	27	24	25	21	22	20	24
Poverty	20	19	26	26	20	19	21	26	24	28
Traffic	20	15	16	10	15	17	12	14	20	9
Public Transportation	11	10	12	16	15	16	11	8	8	8
Availability of Adequate Housing	13	9	9	9	8	6	12	13	15	12
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-3 (CONT'D)

Now I'd like to talk specifically about air pollution or smog. As far as you personally are concerned, do you feel air pollution or smog is very serious, fairly serious, or not a serious problem?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Very Serious	61	70	74	78	77	78	72	61	63	60
Fairly Serious	23	22	20	19	18	16	21	26	28	25
Not Serious	13	7	5	3	5	4	5	11	9	13
Don't Know	3	1	1	-	1	1	2	1	1	1
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-3 (CONT'D)

Do you think air pollution or smog has reached a point where it is a danger for normal, healthy people?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Yes	68	69	67	75	73	74	70	64	60	68
Maybe	14	12	19	9	14	15	12	12	13	10
No	14	16	12	15	11	9	16	19	22	17
Don't Know	4	3	2	2	2	2	1	5	4	5
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-3 (CONT'D)

What do you, personally, think are the main causes of smog or air pollution?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S:Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Auto Exhaust	78	75	81	88	81	81	81	79	80	78
Industry & Factories	64	72	81	79	71	69	78	75	78	74
Bus or Truck Exhaust	19	19	25	21	20	21	15	23	30	17
Aircraft, Jets, Airports	20	18	12	21	19	18	22	17	23	11
Oil Refineries	12	12	12	12	13	17	4	10	7	12
Diesel Trucks	12	11	11	7	11	11	12	11	12	10
Backyard Burning	7	6	3	7	2	1	4	10	6	14
Other	5	5	3	5	5	5	5	4	2	6
Don't Know	5	2	2	1	2	2	1	3	3	3
	(302)	(420)	(227)	(198)	(717)	(528)	(189)	(510)	(242)	(268)

TABLE F-3 (CONT'D)

Do you think there are any people or organizations doing important things to solve the air pollution or smog problem? (If Yes) Who, that is, what persons, groups, or organizations would you say are really doing important things to solve the air pollution or smog problem? Any others?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Yes	59	68	71	73	64	63	68	73	74	72
Major Oil Companies	13	19	19	17	17	17	17	17	18	16
Any Local or County Agency, Like Air Poll. Control Dist.	12	12	16	22	14	14	12	17	19	16
Citizens Groups, College Students	5	12	18	18	13	14	11	14	14	14
Federal Govt. (Any Federal Agency or Congress)	10	10	15	13	10	8	15	14	10	18
Auto Manufacturers	8	10	13	11	10	9	14	10	9	11
Conservation Clubs	4	6	12	19	7	7	6	13	16	10
State Legislature (Legislators)	7	8	9	12	7	7	5	11	9	13
Other Industries	6	7	10	12	9	8	13	7	7	6
Any State Agency (Air Resources Bd.)	3	6	7	9	5	6	3	8	7	9
Don't Know	17	17	9	10	14	13	18	14	16	12
No	37	31	27	26	35	36	30	25	22	27
	(302)	(420)	(227)	(198)	(717)	(528)	(189)	(510)	(242)	(268)

TABLE F-3 (CONT'D)

Many people disagree about who should be taking the lead in trying to reduce air pollution or smog. Which of these groups do you feel should be taking the lead in trying to reduce air pollution or smog?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Federal Government (Washington)	32	25	24	18	24	27	15	28	30	25
State Government	21	18	14	10	16	16	15	16	18	15
City, County, or Regional Govt.	13	15	13	14	13	15	10	15	13	17
Private Industry	11	17	15	18	17	18	13	15	18	12
People Like Yourself	6	6	6	7	5	5	7	8	10	7
All of the Above	35	45	46	54	45	41	54	43	41	44
Don't Know	6	1	-	-	2	2	2	2	2	2
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-3 (CONT'D)

The California Legislature is now trying to decide if cars should be inspected every year for smog emissions. Would you favor required annual inspections of all cars for smog emissions?

	Education				Geographical Area					
	Less than high school %	Completed high school %	1-2 yrs. college %	3 or more yrs.college %	S.Cal Total %	L.A./ Orange %	Other[1] S.Cal %	N.Cal Total %	S.F.[2] Bay Area %	Other[3] N.Cal %
Yes	74	67	74	78	71	69	77	74	71	76
No	20	27	22	17	24	26	19	20	20	20
Don't Know	7	6	4	5	5	5	5	6	9	4
	100 (302)	100 (420)	100 (227)	100 (198)	100 (717)	100 (528)	100 (189)	100 (510)	100 (242)	100 (268)

TABLE F-4

MASS TRANSIT STUDY GROUP TELEPHONE SURVEY

Question Number	Question	(Where Applicable)---	Response Yes	No	Don't Know
1.0	Do you work in or near downtown L.A.?		14.3%	85.7%	
1.1	Do you regularly travel in the direction of L. A.?		41.9%	58.1%	
1.2	How far from home does this trip take you?	Average Distance: 36.5 miles			
1.3	How long does it take you to get there?	22.9 minutes average time; 43.6 mph average speed			
1.4	Do you Drive?		98.1%	1.9%	
1.41	How do you feel about driving? (Of those who answered Yes to 1.4): 25.5% Negative; 38.3% Neutral; 36.1% Positive				
1.5	Could you use the bus to get there?		45.7%	52.2%	2.2%
2.0	Would you benefit from a mass transit system?		50.4%	47.6%	1.9%
3.0	Would the people of Southern California benefit?		84.8%	7.6%	7.6%
4.0	Do you see benefits?		87.6%	10.4%	1.9%
4.1	What would those benefits be? (Of the 92 who said Yes to 4.0): Air Pollution - 51 Time - 22 Other - 48 Congestion - 45 Car Costs - 12 Don't Know - 3				
5.0	How often do you use the freeway system? Never Use - 11.5% Use More than Once per Week - 79.8% Use Less than Once Per Week - 8.6% (5.0 Average Times per Week)				
5.1	At what time of day do you use the freeways? (Of the 83 who use freeways): 6 a.m. - 9 a.m. - 42 Noon - 3 p.m. - 9 6 p.m. - 12 p.m. - 6 9 a.m. - Noon - 8 3 p.m.-6 p.m. - 5 12 p.m. - 6 a.m. -20				
5.2	Are the freeways clear or congested when you use them? Clear - 48.9% Congested 35.5% Moderate 15.5%				
6.0	If the freeways were never congested, would you use them more often?		42.6%	54.5%	3.0%

TABLE F-4 (CONT'D)

7.0	Do you see a need for more freeways in Southern California?		26.9%	70.2%	2.9%
8.0	What fare would you be willing to pay?	Average Fare 71.4¢, but 38.1% did not know.			
9.0	What is the most one should pay?	Average fare 98.4¢, but 21.0% did not know.			
10.0	Should a commuter fare be higher than a rush-hour fare?		12.4%	83.8%	3.8%
11.0	Methods of Financing (Number of Responses: 104):*				
		Property Tax	11	91	2
		Sales Tax	55	42	7
		Gasoline Tax	59	42	3
		Federal Grants	72	29	3
		Private Ownership	55	45	5
12.0	Would you vote for a bond Proposal?		16.2%	80.0%	3.8%
13.0	What type of transportation system would you prefer?				
		Monorail	57.7%		
		Ground Train	12.5%		
		Subway	12.5%		
		Bus	6.7%		
		Freeways	6.7%		
		Don't Know	3.8%		

* - The figures listed are whole numbers, not percentages.

NOTES:
Standard Error of Estimation - .41
Number of Responses - 105
Number Female - 67
Number Male - 38

APPENDIX G

EXPANDED TRANSPORTATION DATA

The following tables contain additional transportation data which were either used for analysis or would be helpful for further analyses. These data come principally from the 1967 LARTS Origin - Destination Study (G-1) and the 1969 A Survey of Average Driving Patterns in the Los Angeles Urban Area (G-2).

Table G-1. Trip Generation by Family Size (Weekday)

Family Size (persons)	Percent of Households	Person Trips Per Household	Person Trips Per Person	Driver Trips Per Household	Driver Trips Per Person
1	21.9	2.3	2.3	1.8	1.8
2	29.6	5.8	2.9	4.4	2.2
3	15.7	8.5	2.8	6.4	2.1
4	14.8	10.3	2.6	7.2	1.8
5	9.5	11.5	2.3	7.4	1.5
6 or more	8.5	12.9	1.9	7.6	1.1

Source: see Reference G-1

Table G-2. Person Trips Per Household By Vehicle Ownership (Weedkay)

Vehicles Available	Los Angeles County	Orange County	Riverside County	San Bernardino County	Verntura County	LARTS Area
0	1.3	0.9	0.8	0.9	1.9	1.2
1	5.5	6.2	6.0	6.8	6.5	5.8
2+	10.2	11.7	11.4	11.9	12.5	10.7
Total	6.8	8.8	7.5	8.4	9.2	7.2

Source: see Reference G-1

Table G-3. Trip Generation by Household Income (Weekday)

Household Income (1967 dollars)	Percent Households	Percent Person Trips	Person Trips Per Hsld.	Driver Trips Per Hsld.
Less than 3,000	10.2	2.8	2.2	1.1
3,000 - 3,999	7.0	3.3	3.8	2.2
5,000 - 4,999	8.6	6.7	6.2	4.3
6,000 - 5,999	9.3	8.3	7.0	4.9
7,000 - 7,999	8.8	8.8	7.9	5.5
8,000 - 8,999	8.0	9.0	8.9	6.3
9,000 - 9,999	8.0	9.5	9.4	6.8
10,000 - 12,499	12.0	16.5	10.9	7.8
12,500 - 14,999	8.1	11.8	11.5	8.4
15,000 - 19,999	6.8	10.0	11.8	8.7
20,000 - 24,999	2.7	4.0	11.8	8.8
Over 25,000	2.8	4.3	12.1	9.1

Source: see Reference G-1

Table G-4. Percentage Distribution of LARTS Employment--1960, 1967

	Los Angeles	Orange	Riverside*	San Bernardino*	Ventura
1960	84.2	6.4	2.6	4.5	2.3
1967	79.0	11.6	2.5	4.3	2.6

* Portion in LARTS area

Source: see Reference G-1

Table G-5. Person Trips By Trip Type Average Weekday

	Home-Other	Other-Other	Work-Other	Home-Work	Home-Shopping	Total Trips
Person Trips	8,503,500	4,156,400	1,698,100	4,974,600	2,856,900	22,189,500
Percent	38.3	18.7	7.7	22.4	12.9	100.0

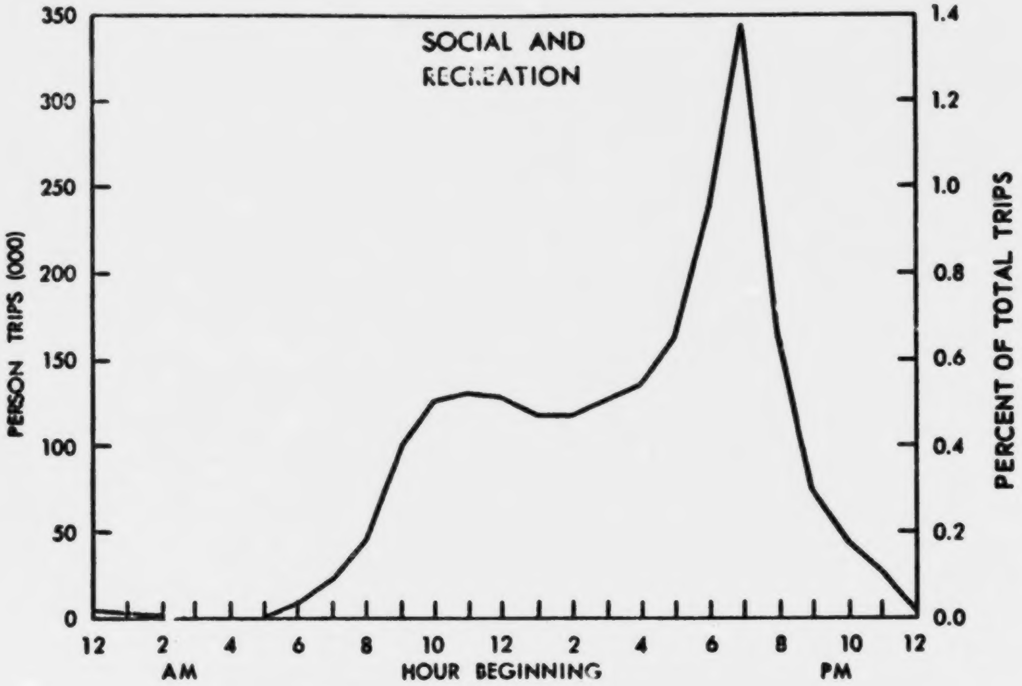
Source: see Reference G-1

Table G-6. Average Weekend Day Trips Compared With Average Weekday Trips

Person Trip Type	Average Weekend Day Volume	Average Weekend Day Percent	Average Weekday Volume	Average Weekday Percent
Home-Other	10,694,500	54.9	8,503,500	38.3
Other-Other	3,744,500	19.2	4,156,400	18.7
Work-Other	330,750	1.7	1,698,100	7.7
Home-Work	1,479,500	7.6	4,974,600	22.4
Home-Shop	3,231,000	16.6	2,856,900	12.9
Total	19,480,250	100.0	22,189,500	100.0

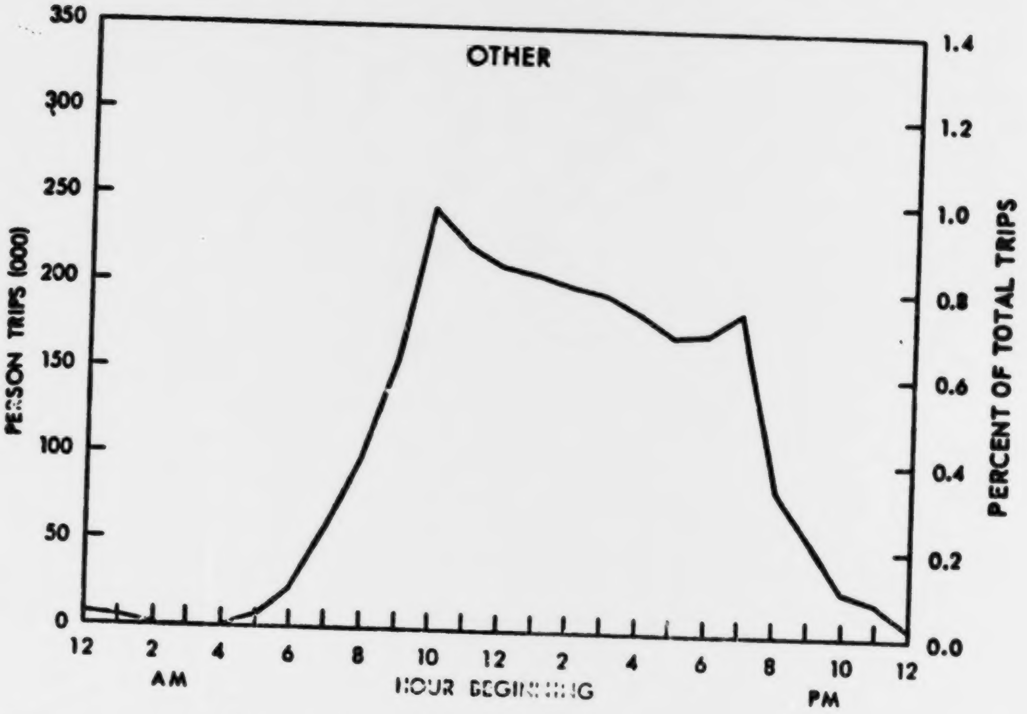
Source: see Reference G-1

Figure G-1. Hourly Distribution Of Person Trips By Trip Purpose At Destination



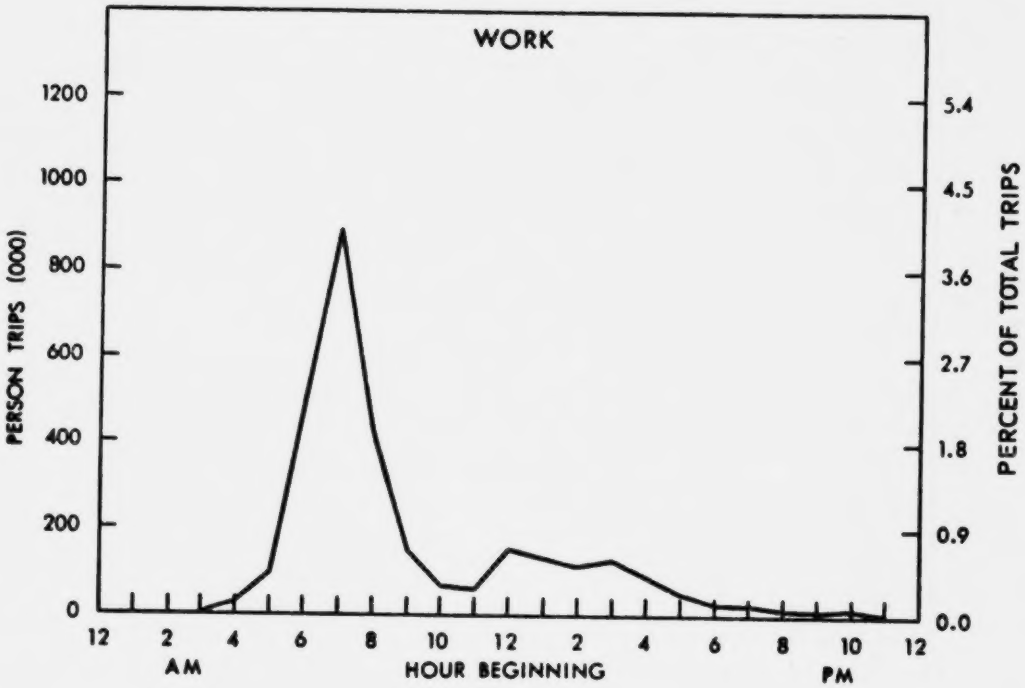
Source: see Reference G-1

Figure G-2. Hourly Distribution of Person Trips By Trip Purpose At Destination (Continued)



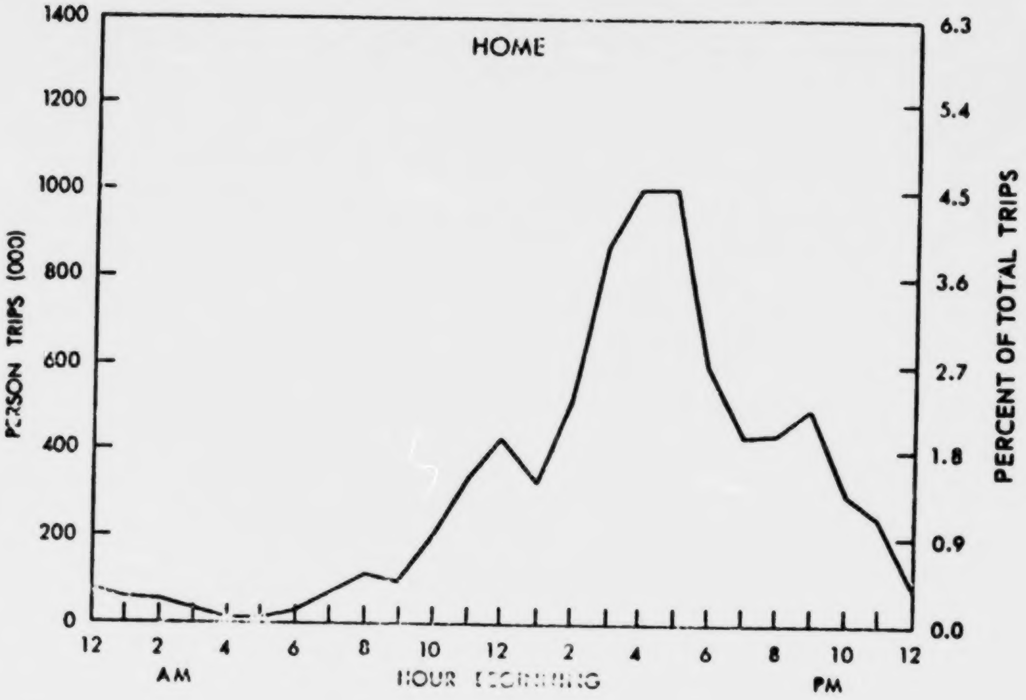
Source: see Reference G-1

Figure G-3. Hourly Distribution Of Person Trips By Trip Purpose At Destination (Continued)



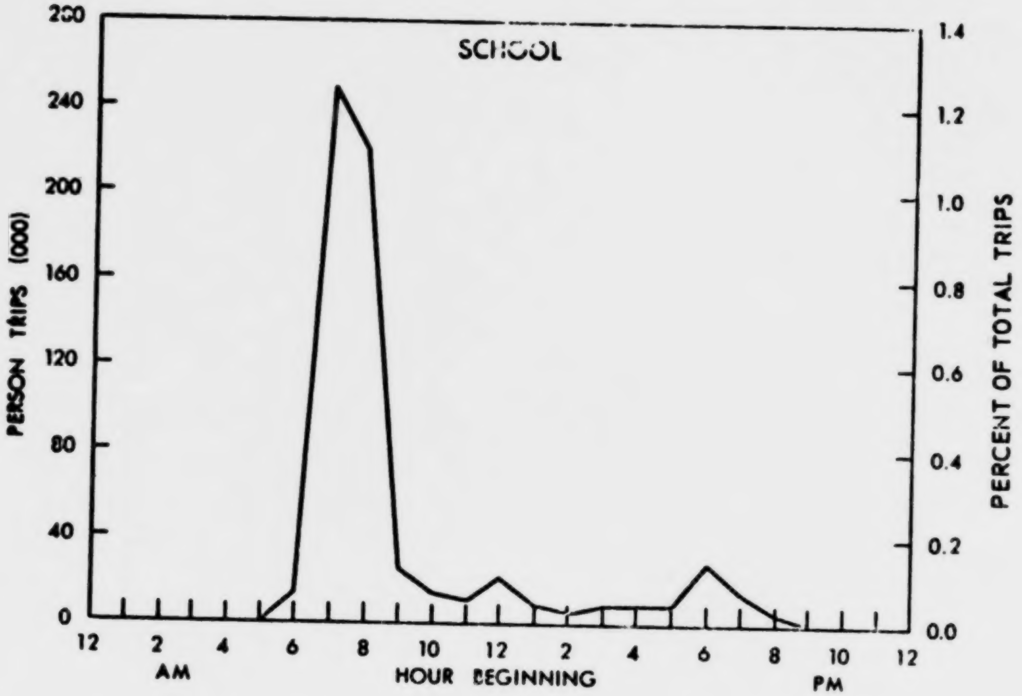
Source: see Reference G-1

Figure G-4. Hourly Distribution Of Person Trips By Trip Purpose At Destination (Continued)



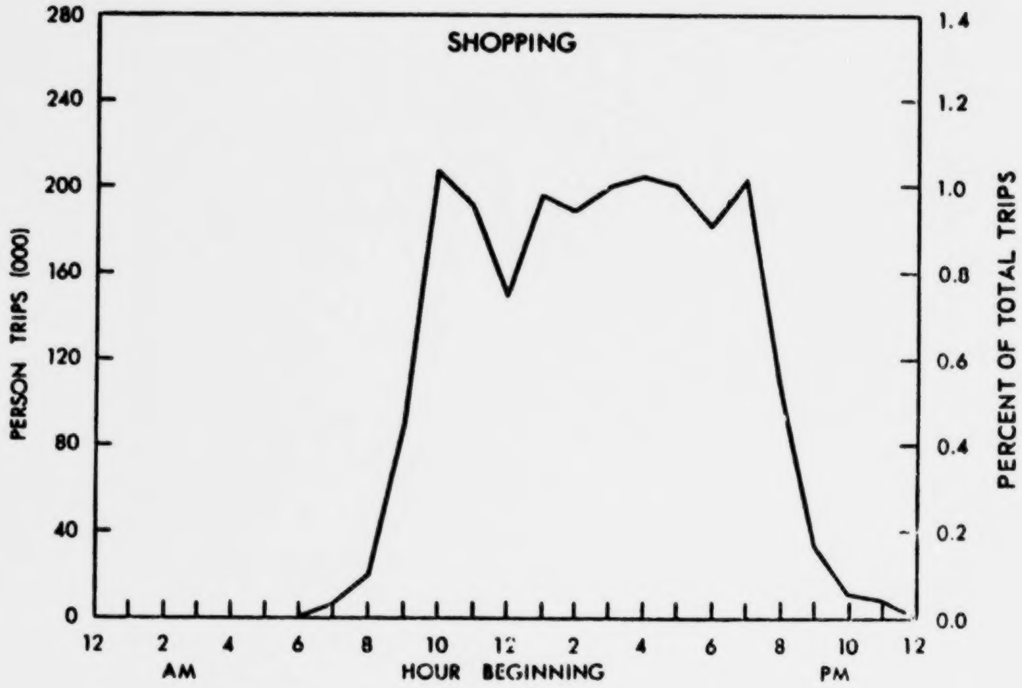
Source: see Reference G-1

Figure G-5. Hourly Distribution Of Person Trips By Trip Purpose At Destination (Continued)



Source: see Reference G-1

Figure G-6. Hourly Distribution Of Person Trips By Trip Purpose At Destination



Source: see Reference G-1

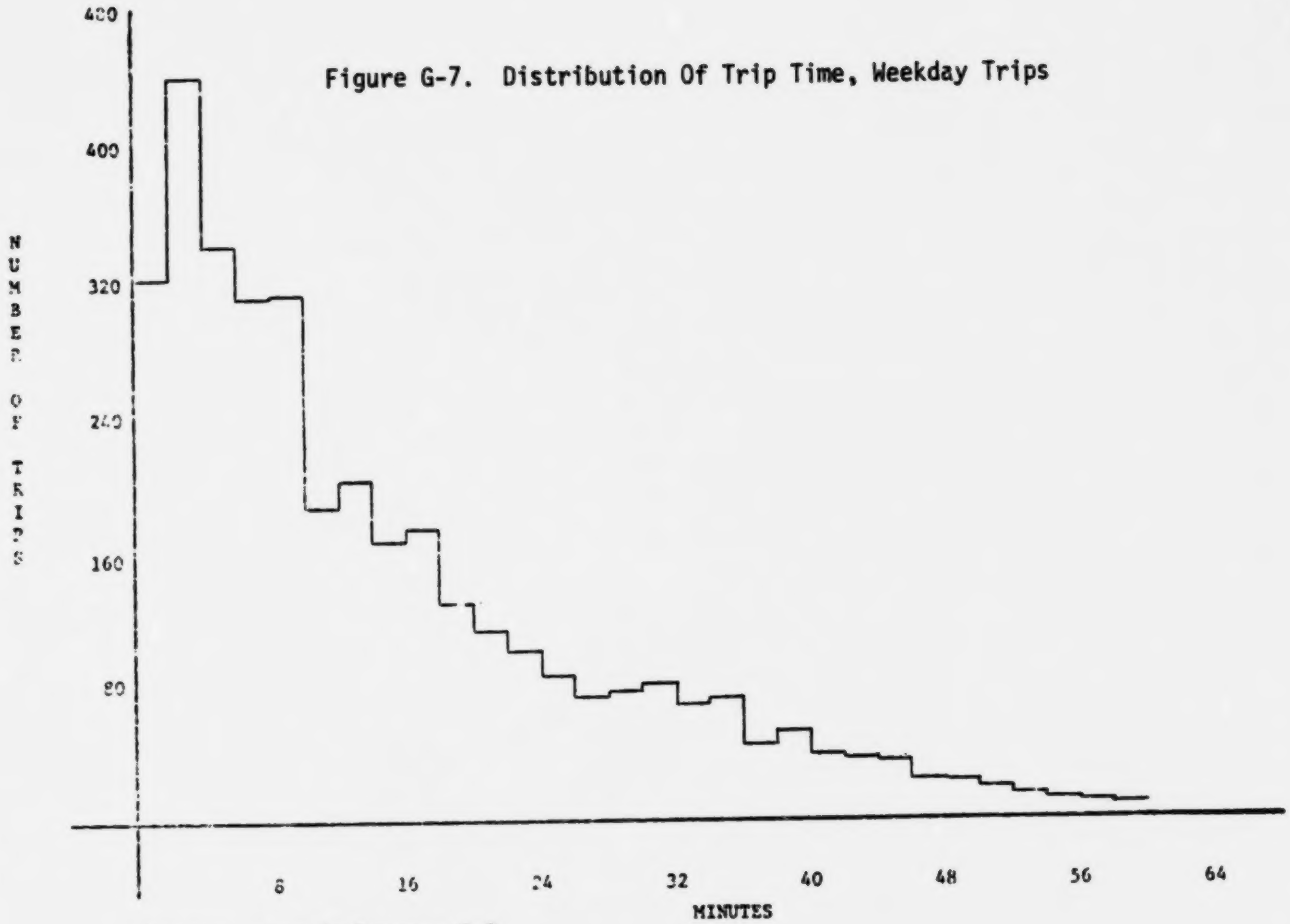


Figure G-7. Distribution Of Trip Time, Weekday Trips

Source: see Reference G-2

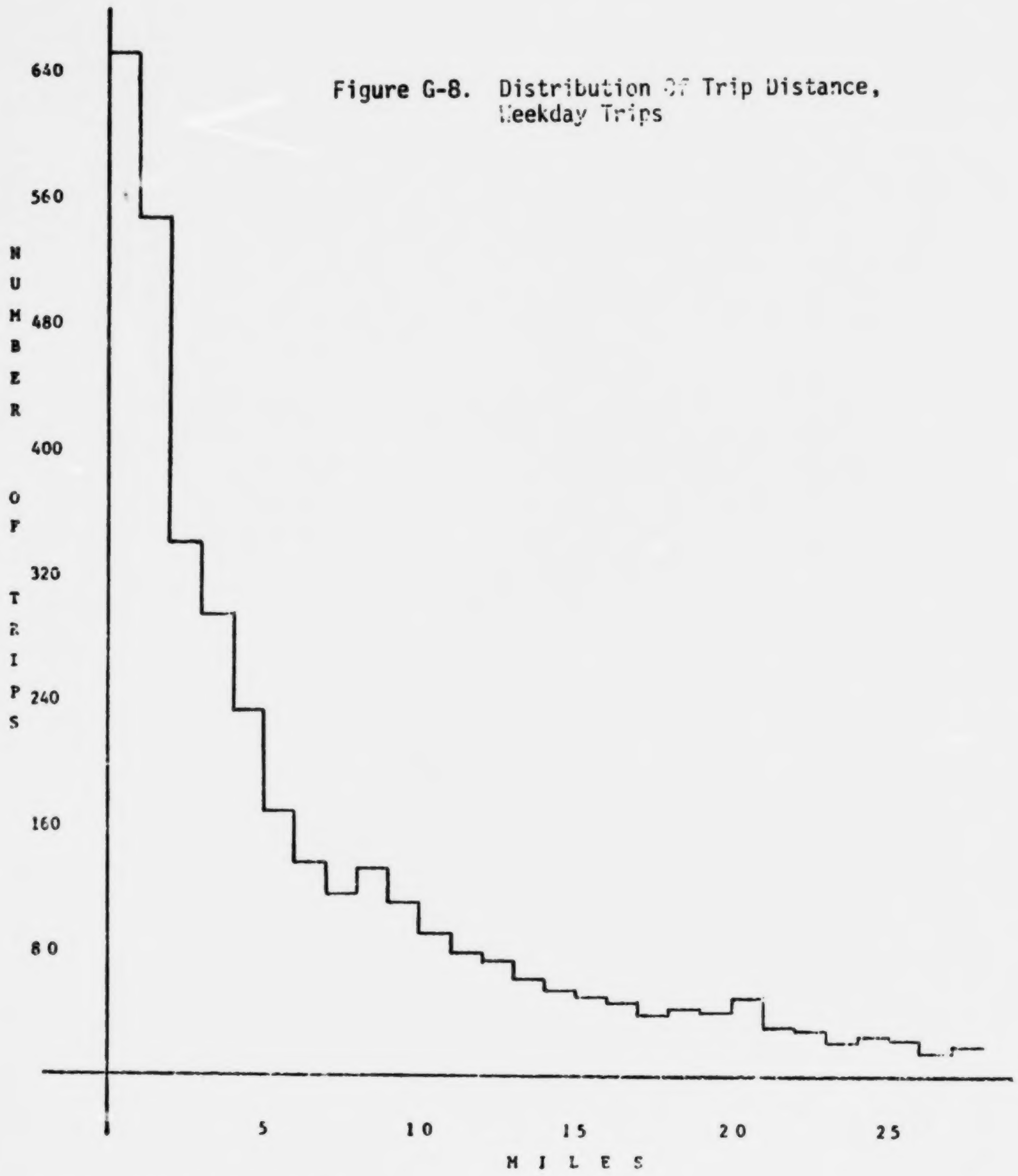
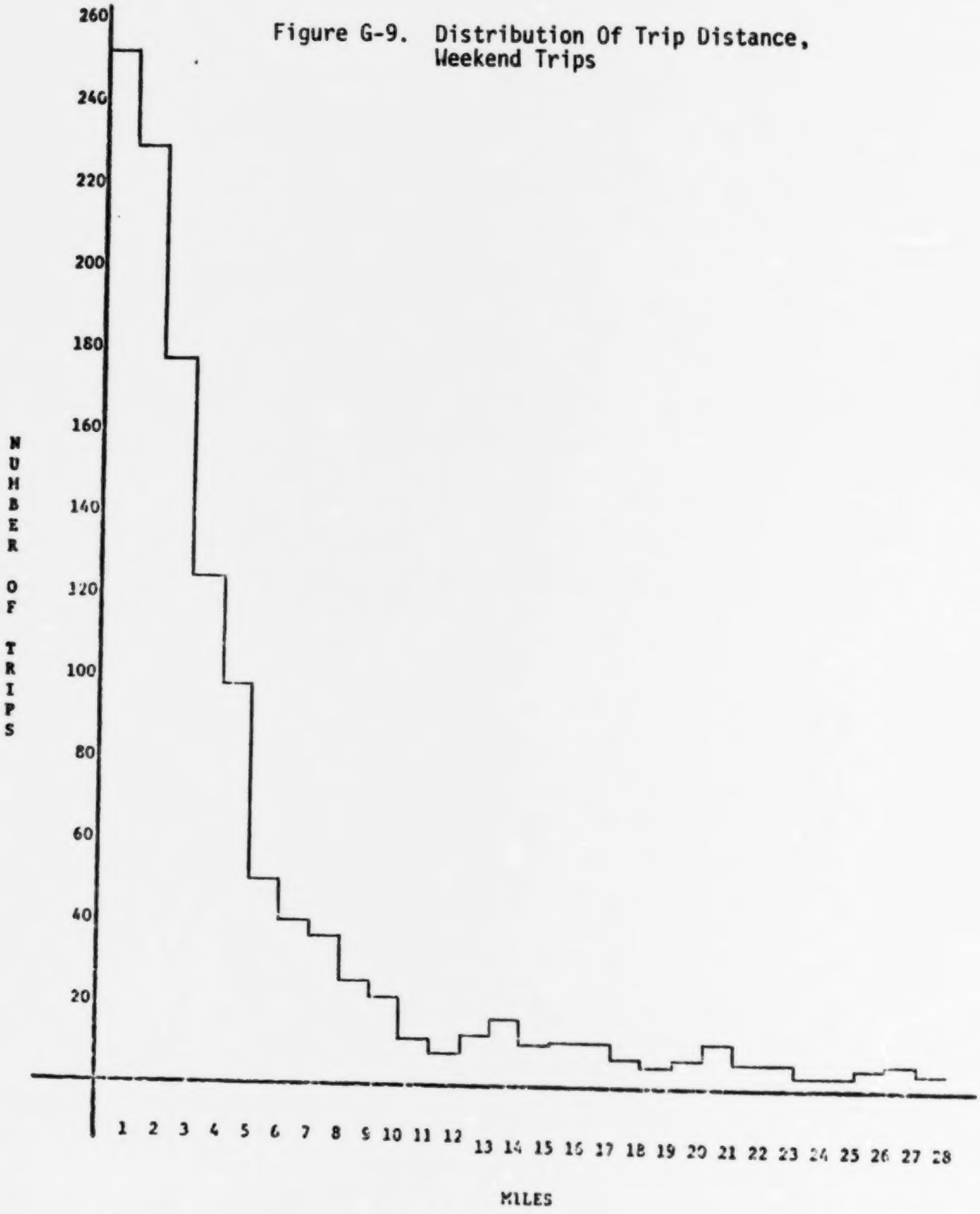


Figure G-8. Distribution Of Trip Distance, Weekday Trips

Source: see Reference G-2

Figure G-9. Distribution Of Trip Distance, Weekend Trips



Source: see Reference G-2

Table G-7. The Typical Three-Trip Day Pattern
(Represents 18% Of All Three-Trip Days, 1.6% Of All Car-Days)

TRIP NUMBER	PURPOSE	SEGMENT NUMBER	ROUTE TYPE	START TIME		MEAN ELAPSED TIME (MIN)	DISTANCE (MILES)		AVERAGE SPEED (MPH)		NUMBER OF STOPS (IDLES)		IDLE TIME (MIN)	
				MEAN	RANGE*		MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**	MEAN	RANGE**
1A	WORK	1	NF	0722	0645 - 0759	15.3	5.8	0.1 - 9.0	27.7	15.0 - 35.0	11.8	4.0 - 22.0	3.6	1.0 - 8.0
	OR:													
1B	WORK	1 2 3	NF F NF	0712	0635 - 0749	8.9 12.2 8.6 29.7	4.7 7.7 3.4 15.[illegible]	0.1 - 6.0 2.0 - 21.0 0.1 - 6.0	28.3 37.7 23.6	15.0 - 45.0 20.0 - 55.0 10.0 - 40.0	4.3 1.5 4.5 10.3	2.0 - 12.0 0.0 - 2.0 2.0 - 12.0	1.3 0.3 1.4 3.0	0.0 - 2.0 0.0 - 1.0 0.0 - 2.0
(TRIPS 1A AND 1B OCCUR IN EQUAL NUMBER)														
2A	SHOP			1724	1653 - 1755	7.2	2.6	0.1 - 4.0	21.8	10.0 - 35.0	5.7	0.0 - 10.0	1.7	0.0 - 2.0
3A	HOME			1754	–	8.5	3.2	0.1 - 5.0	22.5	10.0 - 35.0	7.2	0.0 - 14.0	2.0	0.0 - 5.0
	OR:													
2B	SHOP	1 2 3	NF F NF	17[illegible]0	1632 - 1728	8.4 12.9 3.5 24.8	3.4 7.7 1.6 12.7	0.1 - 6.0 2.0 - 21.0 0.1 - 3.0	24.4 35.8 27.2	10.0 - 40.0 25.0 - 55.0 15.0 - 40.0	5.3 1.9 2.0 9.2	0.0 - 6.0 0.0 - 2.0 0.0 - 6.0	1.4 0.3 0.5 2.2	0.0 - 3.0 0.0 - 1.0 0.0 - 3.0
3B	HOME	1	NF	[illegible]	–	6.9	2.4	0.1 - 4.0	22.5	10.0 - 35.0	5.1	2.0 - 14.0	1.5	0.0 - 3.0
(TRIP SEQUENCES 2A-3A AND 2B-3B OCCUR IN EQUAL NUMBER)														

* RANGE EQUALS MEAN PLUS OR MINUS ONE STANDARD DEVIATION

** RANGE CONTAINS AT LEAST 75% OF ALL CASES (SEE TEXT)

Source: see Reference G-2

REFERENCES:

G-1 California Division of Highways, LARTS Base Year Report - 1967 Origin - Destination Survey, December 1971.

G-2 Kearin, D. H. and Lamoureaux, R. L., A Survey of Average Driving Patterns in the Los Angeles Urban Area, System Development Corporation Technical Memo (TM(1)-4119/000/01).

APPENDIX H

LOS ANGELES METROPOLITAN AREA MODE CHOICE MODEL FOR VARIOUS INCOMES

In section 7.2 of this report the average family income was mentioned as one of the parameters used to determine the number of person trips expected to be made via mass transit for a particular type of trip. Figures H-1 through H-6 of this appendix illustrate the relationship of average family income on transit ridership for a typical home to work trip.

To generate these curves the same assumptions used for development of Figures 7.3 - 7.8 were made and are listed in Table 7.5. In addition, a "high" and "low" level of income were defined by greater than $15,000 per year and less than $5,000 per year respectively. The middle income level shown on these curves is defined as $10,000 per year, the approximate current median income for the Los Angeles area. Figures 7.3 - 7.8 were drawn using the middle income level.

The curves reflect the fact that various income groups perceive differing marginal utility changes for a uniform change in actual conditions. In general, larger percentages of low income travelers will probably find mass transit more attractive than the automobile for a given set of actual conditions under the current attitudes about mass transit in the South Coast Basin.

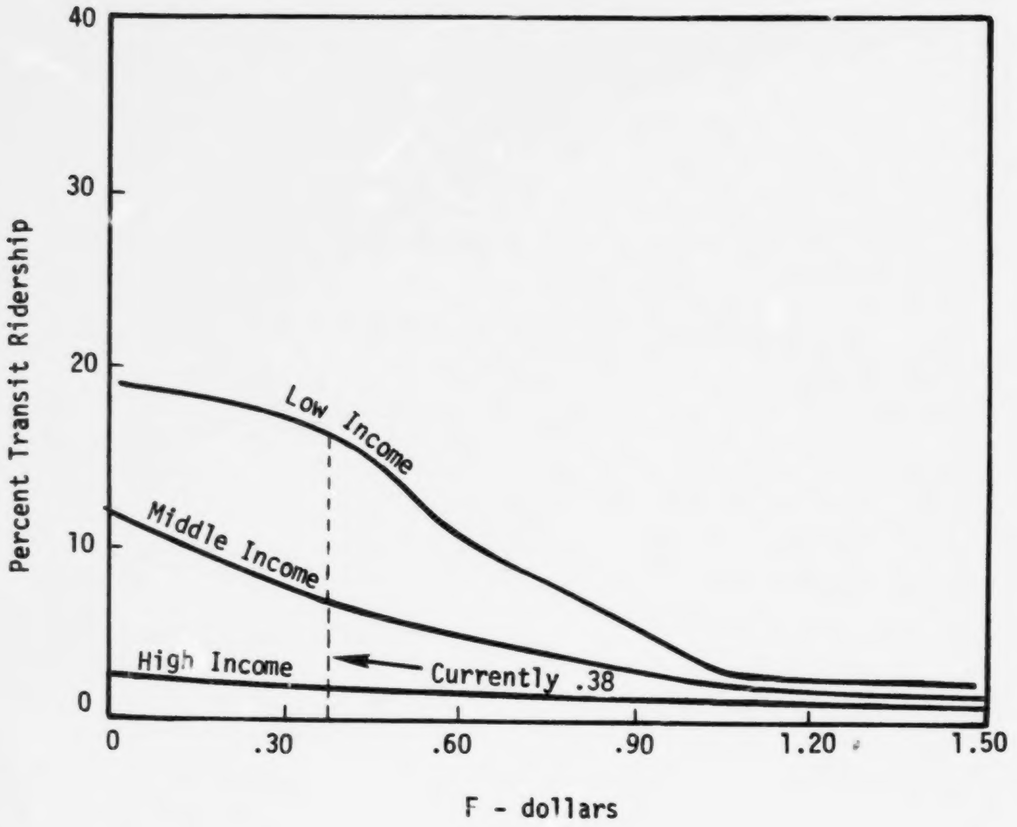


Figure H-1. Transit Fare (One Way) Vs Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

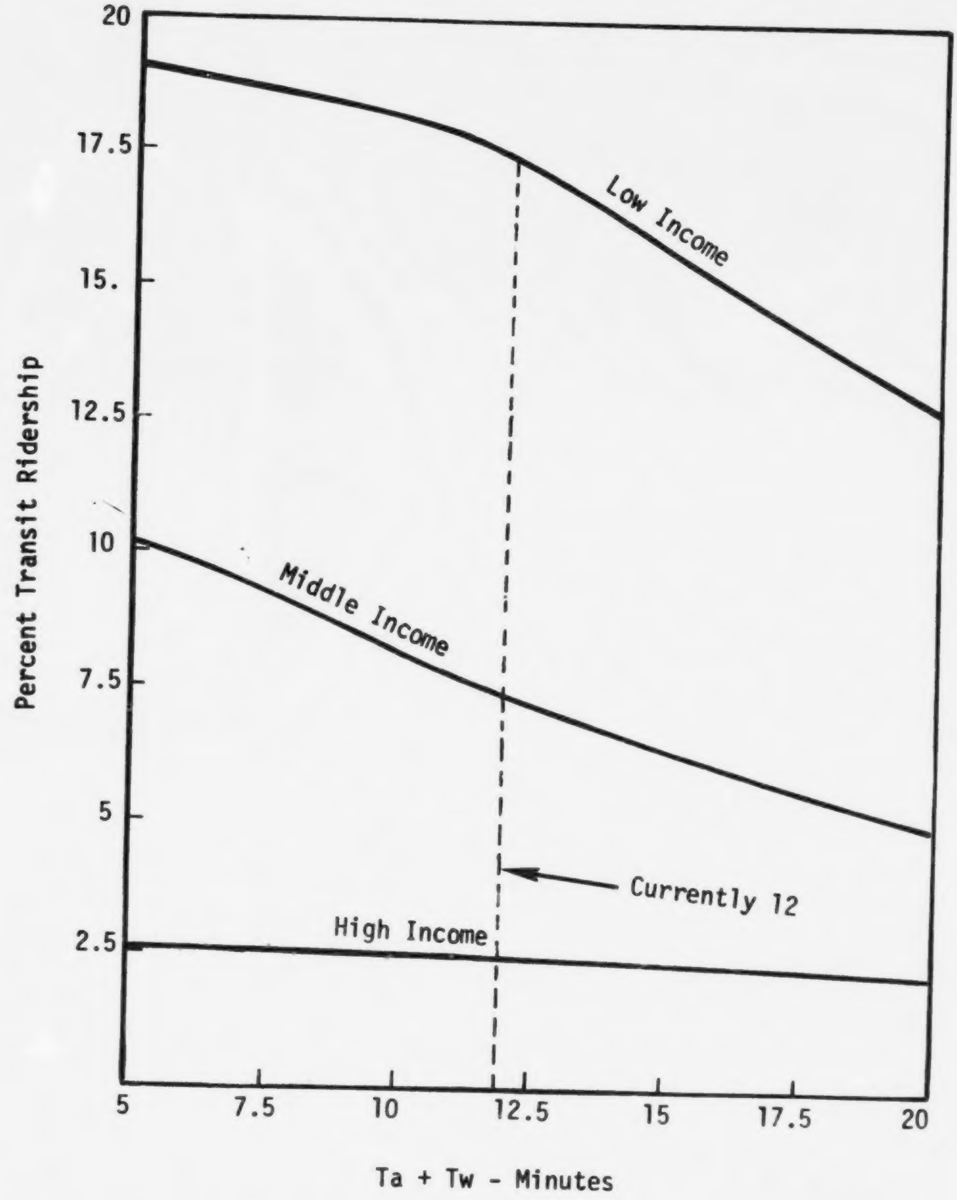


Figure H-2. Transit Access and Waiting Time Vs. Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

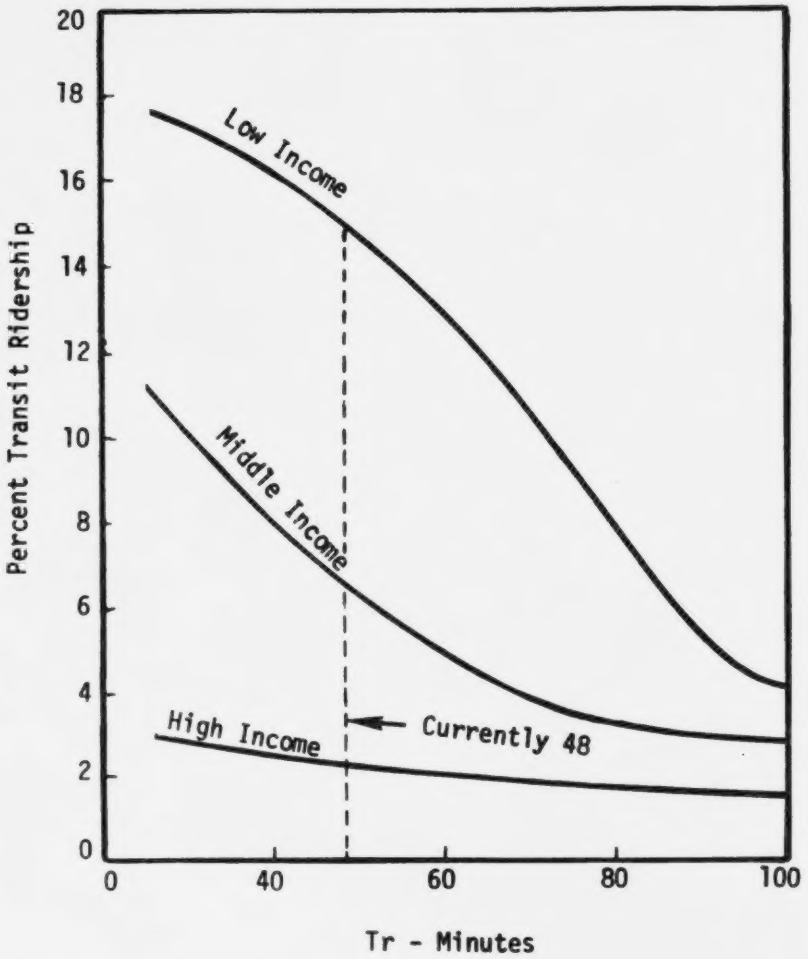


Figure H-3. Transit Riding Time Vs. Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

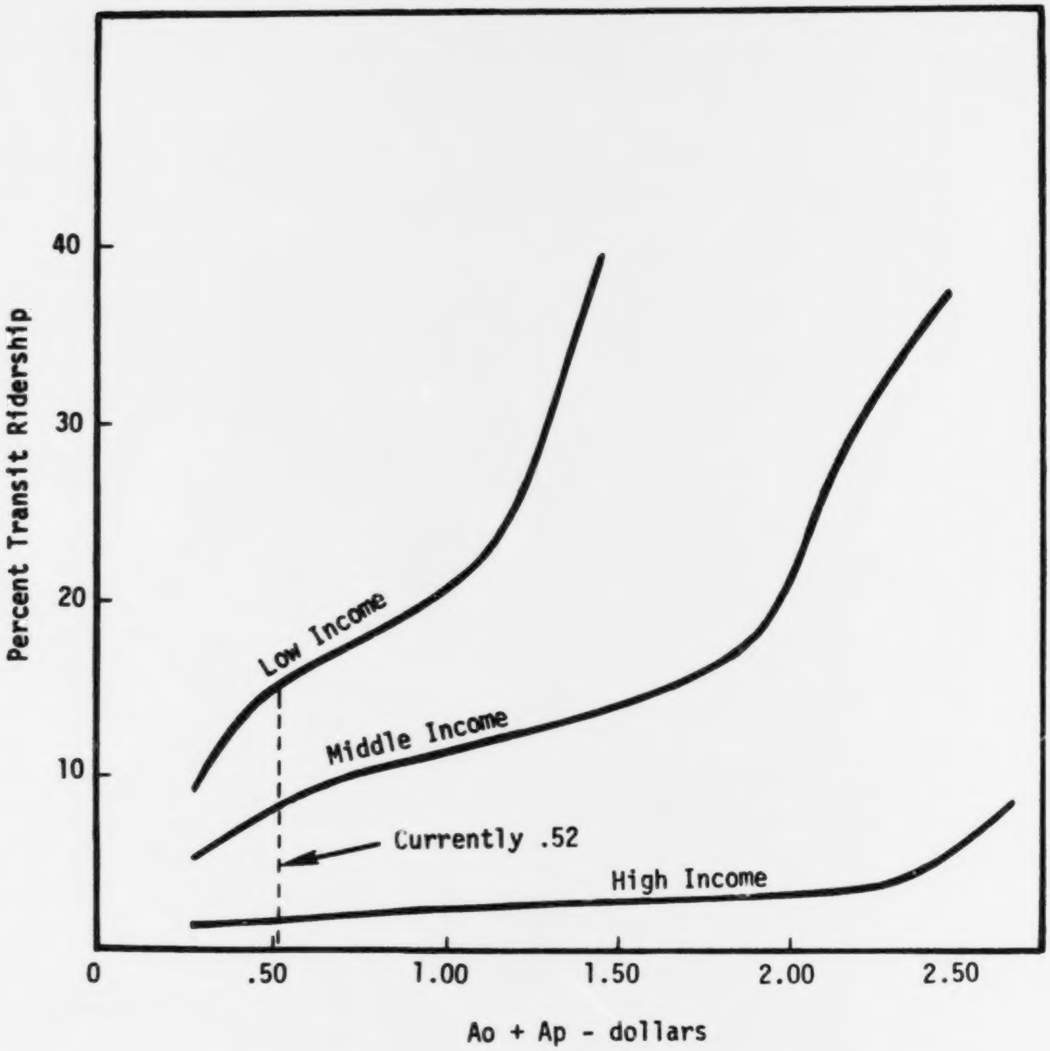


Figure H-4. Automobile Operating and Parking Cost (One Way) Vs. Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

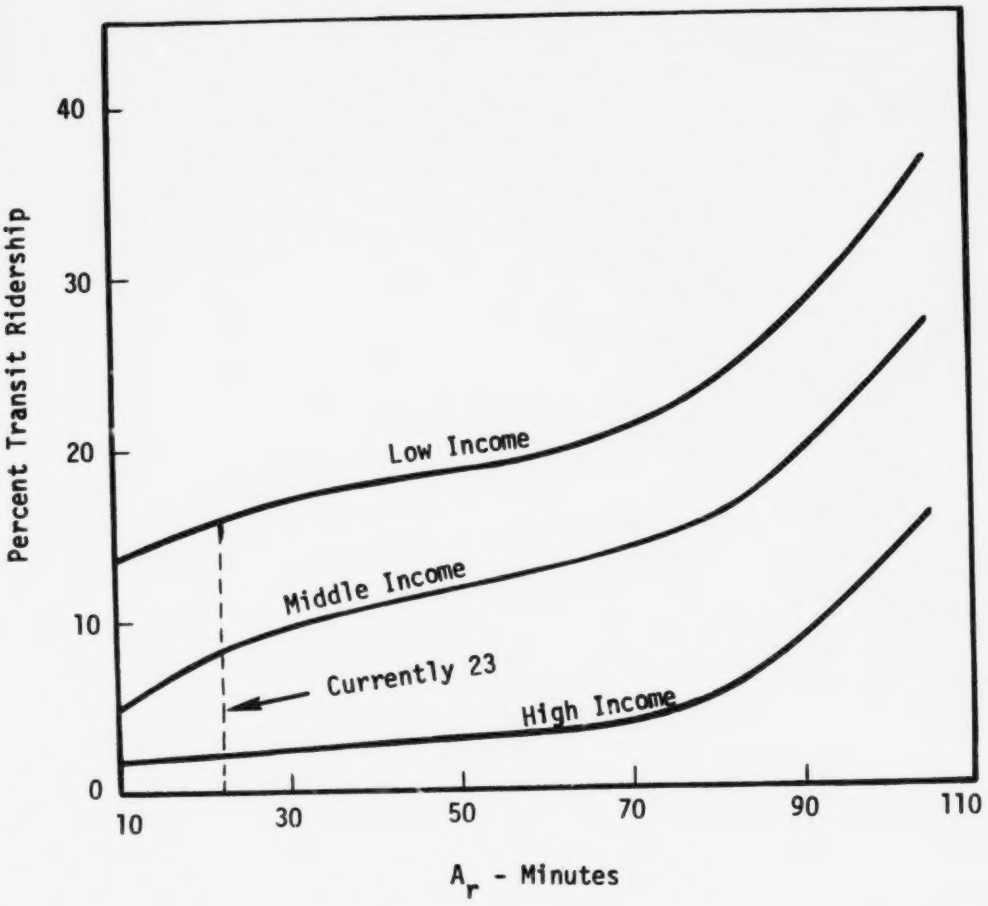


Figure H-5. Automobile Riding Time Vs. Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

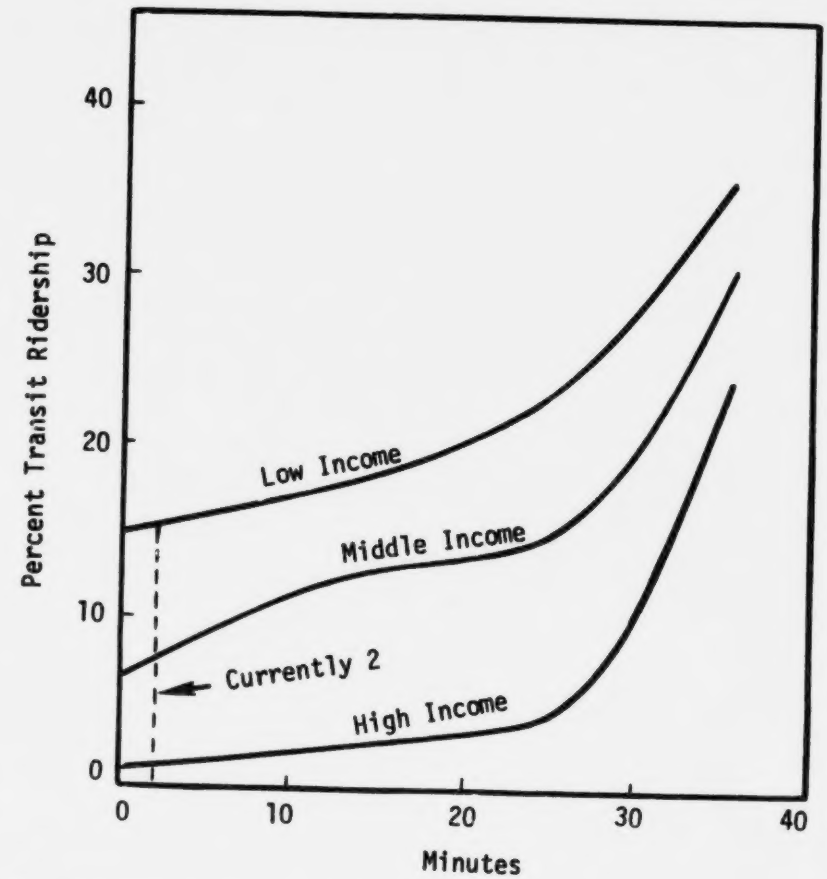


Figure H-6. Automobile Terminal Parking Time Vs. Percent Transit Ridership

Source: Developed from the Los Angeles Metropolitan Area Mode Choice Model

APPENDIX I

GASOLINE RATIONING DURING WORLD WAR II

CHRONOLOGY

April, 1941	The Office of Price Administration (OPA) is formed under the War Production Board to curtail inflation and administer the distribution of essential goods which had become scarce due to the war.
March, 1942	Trial gas rationing begins on the East Coast. The reason is a regional shortage caused by Nazi U-boats sinking American tankers in the Atlantic.
July 1, 1942	Official East Coast gas rationing begins.
December 1, 1942	Official gas rationing is extended to all states in the nation. However, the reason is to conserve the rubber consumption by limiting tire wear. The Japanese had captured 90 per cent of the rubber exporting countries.
December, 1943	By this time, gas rationing throughout the United States was based on scarcity of gasoline. Tire wear had become a secondary concern.
September, 1945	With the end of the war with Japan, gasoline rationing ended.

Administration of Gasoline Rationing Program

Like all of the rationing systems during World War II, the rationing of gasoline was controlled by a system of coupon books. There were basically two types of ration books: highway types, intended for automobiles, motorcycles, etc. and non-highway types for motorboats, farm machinery, etc.

According to an OPA pamphlet written in August, 1942, rationing was "a community plan for dividing fairly the supplies we have among all who need them." Gas rationing officially began in 17 eastern states on

July 1, 1942. This commodity was rationed because of a regional shortage due to Nazi U-boats sinking American tankers in the Atlantic.

A variety of different classes of ration books existed for the highway types. Book "A" was the basic rationing book for passenger cars, whereas Book "B" was the basic rationing book for motorcycles. If a registered car owner could adequately demonstrate that he regularly carried three or more persons in his car to work, or that such a ride-sharing plan was infeasible and alternative transportation was inadequate, he could obtain supplementary rations according to his need. These individuals would be additionally supplied with Book "B" coupons. Ration Book "C," affording mileage greater than that of "B" was for drivers whose driving needs were considered most essential to the war effort. Finally, there were two books ("T-1" and "T-2") for certain commercial operations considered essential to the maintenance of the domestic economy (e.g., trucks, buses, taxis, ambulances, military vehicles, etc.).(I-1)

Each coupon was worth a certain amount of gasoline varying from 2 to 5 gallons. Every quarter the Director of Petroleum decided the value of the coupons, usually allowing from 380 to 470 miles of travel per month. Book "A" contained four pages of seven coupons per page. Coupons on each page were numbered successively. Each page was valid for only a certain period of time (two or three months) and thereafter became invalid. If a person had not used up his coupons during the specified period, he could never use them.

Ration Book "B" (supplement to "A") had 16 coupons intended for three months' use. If the mileage need of the holder was less, the period use was extended. Book "C" contained 64 coupons, good also for a period of three months. "T-1" books contained 96 coupons and "T-2" books contained 384 coupons worth five gallons each. The "D" coupon books contained 32 coupons, with the value of each coupon being less than that for autos.

Rationing was supervised by OPA and administered by local boards comprised of volunteers. However, the Petroleum Administrator for War actually defined the shortage areas and determined the gasoline allotments available for civilians. The Administrator created four different categories for civilian gasoline consumption. The "A" coupons were for pleasure drivers, "B" and "C" for those whose occupation required more driving, and "X" for those with an unlimited mileage need (e.g. government officials, farmers, and others whose driving was essential to the war effort).

In order to obtain a basic gas rationing book, two forms had to be filled out -- one for the coupon book and one for checking tire wear. Another form, OPA R-535, had to be filled out if the applicant desired supplemental rations. The coupons were issued upon receipt of a complete form with the applicant's signature and a valid motor vehicle registration with the applicant's name on it. In order to obtain supplemental rations, individuals had to demonstrate such a need. Proof of additional need was not standardized, and was quite often based on the honor system. In retrospect, the relative ease with which supplemental rations could be obtained turned out to be a major "loophole" in the program.

Initially, basic ration books were distributed during three days (November 9, 10, and 11, 1942). Other ration books were distributed for the rest of the month by the Local War Price and Rationing Boards. By

December 1, 1942, gas rationing was extended to the rest of the nation, primarily to conserve rubber consumption by limiting tire wear. However, at the end of 1943 tanker traffic in the Pacific had become so limited, gasoline rationing for the entire nation was based on scarcity of gasoline.

Records of the number of each coupons issued were kept by the Registrars and Boards. These "Inventory Record Forms" were then sent to the State Director of the OPA, who in turn sent a summary report to the OPA. These records were compiled for comparison of the number of coupons actually used, and the amount of gasoline distributed. The coupons were passed from the car owner to the dealer to the intermediate distributor and finally, to the licensed distributor. The licensed distributor was not required to exchange such coupons to secure replenishment of their supplies. Instead they transmitted all of the coupons they received from the intermediate distributors and dealers along with their State tax form. Again, in retrospect, this reporting mechanism allowed many violations to occur in how much gasoline was actually used.

Another check on the rationing system was accomplished by requiring gasoline dealers and intermediate distributors to register pertinent information with their War Price and Rationing Boards. They indicated on appropriate forms the capacity of their storage tanks and the amount of gasoline at hand at the time of registration. As the war progressed, the administration and issuance of these forms were made easier. First, the application and renewal forms were shortened and simplified. Then, provisions were made for renewal and other board transactions by mail, thus saving time and travel. Also, the ration banking system was applied to gasoline rationing.(I-3)

The standard procedure of rationing gas was nationalized from the east coast policy, but the allotment was more lenient in the western and mid-western states. As of December 1, 1942 pleasure drivers on the Eastern Seaboard states were allowed to travel 378 miles per month while those in other states were permitted 470 miles per month (i.e. about 24% more mileage than the east coast).

When the war with Japan ended September 2, 1945, gasoline rationing ended.

Public Reaction to Gas Rationing

Overall the public saw gas rationing as a necessary burden borne for the war effort. President Roosevelt's message on an OPA explanatory pamphlet in August, 1942 read as follows:

> "We are now in this war. We are all in it -- all the way. Every single man, woman and child is a partner in the most tremendous undertaking of our American history. Ahead there lies sacrifice for all of us.
>
> But it is not correct to use that word. The United States does not consider it a sacrifice to do all one can, to give one's best to our nation, while the nation is fighting for its existence and its future life."

However, when extension of gasoline rationing from the East Coast to the West was considered in Congress, "it was greed with considerable misgiving and opposition in the areas affected."(I-3) "Californians feared rationing would mean a traffic holocaust especially in spread out Los Angeles; they freely used words like 'panic, riot' to describe their fears of what rationing might bring."(I-4)

On a more individual basis, people were confused and bitter because the distribution didn't seem fair. "Many who accepted the "A" cards because they did not have to use their cars for business were bitter when they found that some of their neighbors, who could equally well switch to other forms of transportation, had asked for and received "B" or even "X" cards."(I-5)

The Impact of Gasoline Rationing on VMT

By January 1, 1943, 25 million passenger cars were having their gas intake rationed. Of these autos, 25.4 per cent (6,370,000) were on "B" rations and 14.3 per cent (3,590,000) were on "C" rations. Thus, over half of the civilians were on "A" rations, or the most limited category. The Office of Price Administration estimated the average mileage per car to have been 5,150 miles, which was one-half of the pre-rationing average mileage. The sale of gas dropped 40 per cent from December 1, 1942 to January 1, 1943 in states west of the Alleghenies.

During 1943, total nationwide driving was reduced by 255 million miles daily or 32.6 per cent from total mileage in 1941. On a local level the average mileage reduction was 26 per cent.(I-3)

Problems with Administration and Enforcement

A lot of the administrative problems were ironed out during 1943. But before this time, there were two main problems with administration. First, standards weren't specific enough to actually carry out the fair division of supplies. Proof of need was not required; gasoline rationing was basically on the honor system.

Procedures for obtaining ration books were time-consuming, confusing and impersonal. Since registration for the coupons occurred for only a short period (4-5 days) it was impossible to give individual attention.

Enforcement problems stemmed from an incomplete system of enforcing proper use of coupons. Each car had a window sticker indicating the type of ration book available to the owner. However, if the owner had obtained extra coupons through the black market, these were accepted at many service stations. After five months of rationing on the East Coast, OPA investigators found that 70 per cent of the 500 gas stations in these states were violating gas rationing rules, and distributing more gasoline than they should have. Besides misuse of valid coupons, there was quite a problem trying to halt the distribution of counterfeit coupons.(I-2)

No method was established to inspect filling stations so many of them were bootlegging gasoline.

Finally, a coupon black-market developed. Many of the coupon books for any quantity (X books) created for use by ambulances, hearses, taxis, buses, etc. found their way into the black-market. Thus, those who could afford black-market prices were able to avoid "rationing."

References

I-1. Office of Price Administration, Plan for Mileage Rationing-Instructions for Administrators," Form OPA R-538 (revised 10-1-42), November, 1942.

I-2. __________, First Quarterly Report.

I-3. __________, Fourth Report of the Office of Price Administration.

I-4. Time, December 30, 1942.

I-5. The Nation, March 23, 1942.

Additional references which outline many of the administrative details for how the gasoline rationing program was carried out:

I-6. Office of Price Administration, "Emergency Plan for Gasoline Rationing - Official Information and Instructions for Those Who Will Carry Out the Plan," Form OPA-R-517, 1942.

I-7. __________, "Emergency Plan for Gasoline Rationing - Instructions for Dealers, Dealer Outlets, Suppliers," Form OPA-R-518, 1942.

I-8. __________, "Emergency Gasoline Rationing REgulations," Ration Order No. 5, Title 32, Chapter XI, Part 1394, Form OPA-R-519.

I-9. __________, Gasoline Rationing Instructions," Form OPA-R-538, July, 1942.

I-10. __________, "Plan for Gasoline Rationing - Instructions to Dealers, Intermediate Distributors, Licensed Distributors," Form OPA-R-539,

I-11. __________, "Gasoline Rationing Regulations," Ration Order No. 5A, Title 32, Chapter XI, Form OPA-R-540.

I-12. __________, "Mileage Rationing: Gasoline Regulations," Ration Order No. 5C, Title 32, Chapter XI, Form OPA-R-540 (revised).

I-13. __________, "Instructions for Licensed Distributors," Form OPA-R-550 (revised 10-5-42), November, 1942.

I-14. __________, "Instructions for Licensed Distributors - Supplement No. 1," Form OPA-R-550 (revised 10-5-42), March, 1943.

I-15. __________, "Instructions and Information for Licensed Distributors," December, 1944.

I-16. __________, "Division of Research, Foreign Information Branch, "Gasoline Rationing in Canada," Foreign Information Series, No. 26, November, 1943.

APPENDIX J

RECENT AIR POLLUTION LEGISLATION IN CALIFORNIA

This appendix reviews recent California air pollution legislation related to this contract. Section I discusses legislation enacted into law during the 1971 session; the appropiate chapter numbers for each law are indicated. The summaries of the law and the anticipated impacts have been provided by the California Air Resources Board.

Section II reviews several which were up for consideration during the 1972 legislative session. Unless noted, the status of these bills is presented as of November 8, 1972, when the Senate and House were still in recess. The prospects for most of the bills becoming law are slim; they are presented, however, since several of them are likely to be resubmitted during the next session.

I. Enacted 1971 Air Pollution Legislation

SENATE BILL 578 (Ch. 1507) - Cologne

Requires the ARB to set an emission standard which "significantly reduces" NO_x in 1966 through 1970 cars and light-duty trucks. The primary consideration must be the greatest possible reduction of NO_x. Under this law, a schedule of installation shall be set by the ARB to cover all motor vehicles affected throughout the state.

No device may be accredited if it is less effective than a previously accredited device. 1970 vehicles are exempted if they already meet the California 1971 NO_x standard. The maximum installation price of a device is $35.

A certificate of compliance is required for reregistration in

1973. Until then, enforcement will be through California Highway Patrol (CHP) roadside checks and certificate of compliance upon change of ownership.

The ARB may defer or delete the latter provision for extraordinary and compelling reasons, and the ARB shall report its action and reasons for doing so to the Governor and Legislature. If such action is taken, the schedule of installation may be modified.

ASSEMBLY BILL 936 (Ch. 1095) - Biddle

This bill requires the ARB in cooperation with the CHP to set reasonable exhaust emission standards for cars of model years 1955 through 1965 based on the normal emissions of such cars when tuned up. No smog control device is required. It also requires the owner of any car who has been given notice by a traffic officer that his car does not conform to these standards not to drive the car for more than 30 days without obtaining a certificate of compliance from a licensed smog device station.

SENATE BILL 622 (Ch. 942) - Cologne

This bill authorizes the ARB to accredit a device for installation on 1955-65 vehicles which controls hydrocarbons, carbon monoxide or oxides of nitrogen, if it substantially reduces the emissions of any one of these pollutants without significantly increasing the emissions of the other two.

ASSEMBLY BILL 1591 (Ch. 1073) - Biddle

Whenever the Air Resources Board accredits a pollution control device for used vehicles, it is authorized to establish, in consultation with the Department of Motor Vehicles and California Highway Patrol, a schedule of installation. The schedule of installation cannot be for a period of less than one year. The DMV must require certificates of compliance upon initial registration, and upon change of ownership, in accordance with ARB regulations.

ASSEMBLY BILL 1189 (Ch. 1096) - Biddle

Raises the allowable installed cost of smog devices for used 1955-65 vehicles from $65 to $85 and reduces the durability requirement for such devices from 50,000 miles to 30,000 miles.

ASSEMBLY BILL 937 (Ch. 862) - Biddle

This bill requires manufacturers of motor vehicles to guarantee that each car or truck is built and equipped to conform with the applicable emission standards and that it will continue to conform for the useful life of the vehicle with proper maintenance. It determines useful life of light-duty vehicles (cars) as 50,000 miles or 5 years whichever comes first. For heavy-duty vehicles (trucks) it permits the ARB to set useful life at a longer time or greater mileage.

SENATE BILL 51 (Ch. 1578) - Beilenson

Creates within the Department of Consumer Affairs a Bureau of Automotive Reapir and an advisory board within the bureau. Vests in the Bureau the duty of registering automotive repair dealers. Defines "automotive repair dealer."

Makes it unlawful after June 30, 1972, to be an automotive repair dealer without being registered. Transfers from Department of California Highway Patrol to the Bureau of Automotive Repair the licensing and regulation of lamp and brake adjusting stations and vehicle pollution control device installation and inspection stations.

SENATE BILL 1340 (Ch. 1372) - Wedworth

Requires the Air Resources Board to establish criteria for evaluating the effectiveness of motor vehicle pollution control devices and of fuel additives and to thereafter evaluate such devices and additives. Criteria shall include testing of vehicles when the engineering evaluation indicates testing is warranted. The board may request independent test data.

SENATE BILL 325 (Ch. 1400) - Mills, Deddeh, Alquist

Decreases the state's sales tax from 4% to 3-3/4% and increases limit on local sales tax from 1% to 1-1/4%. Extends both taxes to motor vehicle fuel (previously exempt); these taxes would be in addition to existing state and federal fuel taxes.

The additional revenue raised by the 1/4% increase in local taxes is set aside for transportation development. The revenue may be spent only after approval of expenditures by regional transportation agencies, which approval must comply with regulations designed for the purpose by the State Transportation Board.

In counties exceeding 500,000 population, the revenue must be spent for the development, maintenance and operation of public transportation systems; in smaller counties, the revenue may also be used for right-of-way acquisition and construction of local streets and roads.

The bill does not establish criteria by which the regional agencies must dispense the revenue; no emphasis is placed on rapid transit or any other form of public transit.

Legislation Reviewed during the 1972 Legislative Session
(all bills mentioned were still being evaluated as of November 8, 1972)

ASSEMBLY BILL 69 - CREATION OF DEPARTMENT OF TRANSPORTATION
Deddeh, Lanterman, Schubarum, Hayden, Sieroty

The purpose of this bill is to coordinate the various transportation planning agencies on a state and regional level. This is to be accomplished through the creation of a Department of Transportation and an altered State Transportation Board.

The Office of Transportation Planning and Research, Department of Aeronautics, and Department of Public Works are abolished and their responsibilities and duties are usurped by a new Department of Transportation in the Business and Transportation Agency. The State Transportation Board is removed from the Business and Transportation Agency and a Board Office is set up.

The Transportation Board allocates money for transportation research and planning from the new Transportation Planning and Research Account in the State Transportation Fund when these funds are appropriated by the Legislature. The Department is required to prepare a California Transportation Plan (a study to coordinate and develop a balanced transportation plan and policy), to be submitted to the State Transportation Board. The Board must adopt it and send it to the legislature no later than January 1, 1976. For the succeeding two years and biennially thereafter, the Director must submit a proposed updating of the Plan.

Two progress reports of the Plan are required to be sent to the Board for approval and recommendations, and then onto the Legislature. The Legislature must receive the first report by July 1, 1974, and the second by January 1, 1975.

Implementation of the Plan cannot begin until legislative authorization is received. This is to occur after they receive a report including planning, construction, operation and control of resource allocation for transportation by January 15, 1973.

Each transportation planning agency as designated by the Government Code must prepare a proposed regional transportation plan and submit it to the Department by April 1, 1975. Such a plan must be submitted annually for the succeeding two years, and biennially thereafter.

Money for the California Transportation Plan will be appropriated by the Legislature and allocated by the Board from the Transportation Planning and Research Account. Also, some of the money in the Motor Vehicle Transportation Tax Account will be allocated to the Transportation Planning and Research Account.

This bill places the California Toll bridge authority in the Department of Transportation and includes the Department of Alcoholic Beverage Control in the Business and Transportation Agency. If passed, this Act will become operative on July 1, 1973.

Status: This bill will be considered by the Assembly Committee on Finance November 10, 1972. It is also being considered by the Governor's Cabinet. It has a good chance of passing both houses and becoming law.

NOTE: This bill has passed both houses and is now before the Governor. Since he favors the bill, it is very likely he will sign the bill into law (December, 1972).

ASSEMBLY BILL 391 - AIR POLLUTION CONTROL FOR PASSENGER VEHICLES

Foran

This act requires the State Air Resources Board to adopt passenger vehicle emissions test procedures and standards. The Board may, with the cooperation of the Department of California Highway Patrol, also inspect the mechanical condition of the passenger vehicles.

Certificates of compliance will be issued by authorized inspection stations when a vehicle meets the adopted standards and when a standard fee is paid. These fees will be deposited in the Air Pollution Control Fund. Upon initial registration or renewals thereafter the Department of Motor Vehicles will require a Certificate of Compliance in the South Coast Air Basin. Motorcycle owners are exempt.

The Department of Motor Vehicles is required to implement a system for the year-around renewal of passenger vehicle registration. Related changes in the Revenue and Tax Code and the Vehicle Code are to be made. An unspecified amount is appropriated from the Motor Vehicle Account for the Director of Finance to allocate to the Board and the Department. The amounts to be received are not specified.

The State Air Resources Board, in cooperation with the Department of Consumer Affairs, is required to prepare a handbook containing information about the inspection program and to distribute these handbooks. This is considered an urgency statute to take effect immediately. Portions of the act will become operative on the date specified by the Board no earlier than January 1, 1973 and not later than January 1, 1974.

Status: This bill will probably die because the Administration is against it.

ASSEMBLY BILL 406 - AIR POLLUTION CONTROL BY VEHICLE INSPECTION

Deddeh, Foran, Biddle

Provides for an annual inspection of motor vehicles in the South Coast Air Basin of California to check pollution devices, educate the consumer, improve the safety characteristics of motor vehicles and to reduce vehicular noise emission levels.

A seven-member State Motor Vehicle Inspection and Maintenance Commission is created to:

1. Set up the annual motor vehicle inspection program.
2. Apply for federal funds in order to implement pollution inspection, safety inspection and consumer information.
3. Upon receiving federal funds, implement such an inspection program.
4. Lease, buy, or construct facilities and advanced inspection equipment capable of providing diagnostic information for motorists.
5. Establish regulations and standards to carry out the program.
6. Establish standards by which low income persons may qualify for assistance for bringing their motor vehicles up to safety and pollution emission standards.
7. Compile data from annual inspection and to compare this data with that obtained from the same area the previous year.

Requires the Department of Motor Vehicles to provide for a staggered system of vehicle registration in the South Coast Air Basin. Makes it illegal to sell a used vehicle which does not have proof of compliance with the inspection. Makes the program contingent upon receiving a commitment from the Federal government for up to 50 per cent of the total cost from federal funds for at least three years. If the federal government agrees, the program will begin March 1, 1974. Other funds ($6.2 million) will be appropriated from the Motor Vehicle Account in the Transportation Tax Fund for administration and other specified costs.

Status: This bill has passed the Assembly and is now in the Senate Committee on Government Organization. It may pass the Senate, but chances are not very good it will be signed by the Governor.

ASSEMBLY BILL 886 - AIR POLLUTION CONTROL BY INSPECTION OF MOTOR VEHICLES

Biddle, Quimby

The California Highway Patrol is required to establish and maintain inspection stations which check emission control devices in vehicles having a gross weight under 6001 pounds. These stations must be functioning by the beginning of 1974 for the South Coast Air Basin, and by 1977 for the remainder of the state.

A sticker valid for 12 months will be issued to a vehicle meeting the requirements of the inspection station, and when a $2 fee is paid. The revenue from the fee will be deposited in the Motor Vehicle Account. The Department of Motor Vehicles requires every vehicle to have the sticker on its windshield upon initial registration and renewal of registration.

On or after the 121st day after the final adjournment of the 1972 Regular Session of the Legislature, or January 1, 1973, whichever is later, no such specified vehicle, whose owner lives in the South Coast Air Basin, can legally be operated upon a highway unless its vacuum spark advance is disconnected or it is equipped with a vacuum spark advance disconnect approved by the Board. Vehicles which cannot operate with their vacuum spark advance disconnected can obtain exemptions from the Board.

Status: This bill is in the Assembly Committee on Transportation where it will probably die.

SENATE BILL 661 - MOTOR VEHICLE AIR POLLUTION INSPECTION

Beilenson

Provisions are made to establish a pilot program in the South Coast Air Basin for periodic inspection and testing of motor vehicles. The State Air Resources Board is required to prescribe maximum air pollution emission standards to used when testing motor vehicles in this program. Supervision and administration of the program will be handled by the Department of Consumer Affairs, the California Highway Patrol, and the State Air Resources Board.

If repairs are made on a vehicle by a licensed motor vehicle pollution control device installation and inspection station in order to meet inspection and testing requirements, the station must guarantee that such repairs will meet inspection and testing requirements for a 12-month period. Furthermore, any additional necessary repairs must be made by the station free of charge until the motor vehicle satisfactorily completes inspection and testing.

Financially, this bill appropriates a specified sum (not yet specified) from the Motor Vehicle Account in the Transportation Fund in order to administer the program. It reduces the amount to be spent for state highway construction in southern counties by forty per cent of the amount appropriated from the Motor Vehicle Account. The same amount of money is to be spent in state highway construction in northern counties. The reimbursement for this appropriation will only be available to state highway consturction in County Group No. 2 (southern counties).

Status: This bill is up for its Third Reading in the Senate. Since the Administration is against it, it will probably die.

SENATE BILL 657 - FLEET VEHICLE AIR POLLUTION

Beilenson

This legislation requires every 1970 or later year model fleet vehicle operating in the South Coast Air Basin to be equipped with a "gaseous" fuel system which permits the vehicle to operate on compressed natural gas, liquified natural gas, or liquified petroleum gas by December 31, 1974. If a fleet vehicle does not comply by this date, its operation will be illegal.

The power of enforcement is provided by the Department of Motor Vehicles. When vehicle registration begins in 1973 a valid certificate of compliance must be presented to register, re-register, or transfer ownership. The certificate is obtained from a licensed motor vehicle pollution control device installation and inspection station.

The gaseous fuel use tax will become ineffective on December 31, 1975 except to fleet vehicles complying with this act. A fleet vehicle first registered prior to December 31, 1975 and complying with this act can apply for an additional five years fuel tax exemption.

The amount expended for the construction of state highways in County Group No. 2 (southern counties) will be reduced by 40 per cent of the reduction in funds tranferred to the State Highway Account due to this act. An amount equal to this 40 per cent will be expended for construction of state highways in County Group No. 1 (northern counties).

Status: This bill has been passed by the Senate and will come before the Assembly Committee on Transportation November 16, 1972. Since the Administration is against this bill, it does not stand much chance of becoming a law.

NOTE: This bill was killed in the Assembly Committee on Transportation on November 16, 1972. Eight votes were needed to get the bill out of committee; the final vote was 5 votes for, 5 votes against, and the remaining committee members either abstaining or absent.

Since November 8, 1972, it has been learned that all of the bills reviewed in this section II, except for A.B. 69, have died. The two major factors for this are: 1) a lack of demonstrated public support and interest in the bills and 2) opposition by the administration for passage of the bills.

APPENDIX K

STUDY CONTACTS

This program was initiated in Sacramento on September 15, at the Air Resources Board main headquarters. The agencies, institutions, and companies represented were EPA, TRW, Inc., DeLeuw, Cather and Company, California Department of Public Works, and the Air Resources Board. Subsequent meetings in San Francisco, Sacramento, and Los Angeles, resulted in several other agency involvements.

The bulk of the data used in this study came from a limited number of sources; these are listed below as primary contacts and data sources. In an attempt to insure that "all the bases were covered," many other individuals and groups were contacted; these sources are presented for completeness as "secondary contacts and data sources."

Primary Contacts and Data Sources

California Air Resources Board
Sacramento, California

Harmon Wong-Woo
Gladys Meade
John Maga
Don Bratton

California Department of Public Works
Sacramento, California

Robert Watkins

California Division of Highway, District 7, Advanced Planning
Los Angeles, California

John Shaver
John Reeves
Bob Blythe

California Division of Highways, District 7, Freeway Operations
Los Angeles, California

Jesus Garcia
Richard Green
Robert Kahn

Southern California Association of Governments
Los Angeles, California

William Ackerman
Ed Holden
Brian Farris

Environmental Quality Laboratory - California
Institute of Technology
Pasadena, California

Lester Lees
Ken Heitner
Mark Braly
Mahlon Easterling
James Krier

Southern California Rapid Transit District
Los Angeles, California

John Curtiss
Frank Barnes

Operation Oxygen
Pasadena, California

Jack Novak

Regional Planners Association
Los Angeles, California

Phil Ashabraner

Massachusetts Turnpike Authority
Massachusetts

John Driscoll

General Services Administration
Washington, D. C.

Dick Dockus

Secondary Contacts and Data Sources

California Air Resources Board
Los Angeles, California

- Norman Kayne
- Raymond Ingels

Environmental Quality Laboratory - California Institute of Technology
Pasadena, California

- John Trijonis
- Gary Rubenstein

City of Los Angeles Traffic Department
Los Angeles, California

- Walter Schroeder
- James Fuller
- S. E. Rowe
- Larry Glazer

Orange County Transit District
Anaheim, California

- Peter Fielding

University of California - Los Angeles
Los Angeles, California

- Don McAllister
- Don Ratajczak
- James Fountain

APPENDIX L

EVAPORATIVE LOSSES FROM SERVICE STATION FUELING OPERATIONS

The handling and transfer operations associated with the sale of gasoline contribute a substantial portion of hydrocarbon emissions through evaporative losses. As exhaust emission control standards for motor vehicles become more stringent, the proportionate share of hydrocarbon emissions coming from evaporative losses will increase. Various regulations have been aimed at controlling certain gasoline transfer operations. This section attempts to review hydrocarbon losses from what are normally the last two fuel handling operations -- the filling of underground storage tanks at the service station and the filling of automobile gasoline tanks from these storage tanks. Estimates of the tonnages lost from these sources are given and a review of some emission control techniques presented. Where available, cost estimates and lead time estimates for implementing control procedures are also given.

Several studies have approximated the hydrocarbon losses in Los Angeles from service stations for 1967 (L-1, L-2). These losses were about 28 tons per day from filling underground storage tanks and 60 tons per day from automobile filling procedures. Expanded to include the entire South Coast Air Basin using the gasoline consumption projections given in Figure 2-7, the combined uncontrolled emissions from these two sources become approximately 132 tons per day in 1972 and 159 tons per day in 1977. These projections assume the limit on Reid vapor pressure from April through October as set forth by the CARB. Assuming no control methods are instituted, these two sources become a significant air pollution source by 1977.

Data on the exact number of storage tanks in use in the South Coast Basin are not generally available. However, it was estimated there were approximately 32,200 permits for storage tanks in Los Angeles County in 1971 (L-5). Since the permits are required for installation and are not cancelled when tanks are removed or destroyed, the number quoted is probably high for storage tanks actually being utilized. Because these tanks are valuable and frequently reused, it has been assumed there were 31,000 tanks in actual use in 1971.

Using the same growth projection as before (Figure 2-7), expanded estimates for the South Coast Basin can be made. This implies there are currently about 14,000 service stations, 42,000 storage tanks, and 126,000 pumps in operation, approximately 470 tank trucks are required to service these storage tanks.

In projecting the number of stations and related equipment for 1977, a growth factor of less than 2% has been assumed (about half the projected growth in gasoline consumption). This was done partially because of the growing resistance to the increase in stationary sources which will tend to limit future growth, e.g. the existing moratorium on service station construction in San Francisco. If the projections hold for 1977, the South Coast Basin can expect about 15,000 service stations, 45,000 storage tanks, 135,000 pumps, and 500 tank trucks. Table L-1 summarizes the data related to service staions.

Table L-1

Projections of Service Stations and Related Equipment
(South Coast Air Basin)

	1972[a]	1977[b]
Service Stations	14,000	15,000
Storage Tanks	42,000	45,000
Pumps	126,000	135,000
Tank Trucks	470	500

[a] Extrapolated from data for Los Angeles County.
b Assuming < 2% annual growth.

Gasoline Modification - Reid Vapor Pressure Change

One method of lowering the evaporative losses is to change the composition of the gasoline, e.g. by changing the vapor pressure. Such a change requires a complete analysis of the impact on all emissions subsequent to the change and the resultant change in photochemical reactivity of the modified fuel. According to Nelson (L-2), lowering the Reid vapor pressure from the present 9.0 psi to 6.0 psi reduces the expected evaporative emissions by 27%. For the Basin in 1977, this implies a reduction from stationary automotive servicing sources of 43 tons/day (from 159 tons/day to 116 tons/day).

On the other hand, a joint study by the CARB, LAAPCD, and Western Oil and Gas Association (L-1) found much less benefit from such a fuel composition change. Although, the study found the average percentage gains in emissions from stationary sources to be in good agreement with Nelson, the total net reduction was considerably less. Overall, the CARB study concluded a change in Reid vapor pressure from 9.0 psi to 6.0 psi would produce only a net hydrocarbon emission reduction of 9%.

The key consideration was that "in general, a reduction in vapor pressure using fuels like the prototypes would produce a reduction in emissions due to evaporation of gasoline, an increase in exhaust hydrocarbon emissions, and a decrease in the total organic emissions associated with both gasoline associated sources and all sources, mobile and stationary" (L-1).

In addition, if one considers the impact of the reactivity change, the net benefit from a change in Reid vapor pressure becomes even less yet. Using the R-1 reactivity scale, it was concluded the overall gain from all gasoline related emission sources drops to about 4-5 per cent and if the R-2 reactivity scale is used, the equivalent gain becomes only 1.2 per cent. Thus, when the total resultant hydrocarbon losses (evaporative and exhaust) and the reactivity questions are considered, the gains in hydrocarbon improvements become quite low. If one goes on further to examine the cost associated with such a fuel composition change, the cost effectiveness of this strategy becomes very marginal.

At least two studies have reviewed the cost of such a change. The first (L-6) estimated capital costs at some $60 million and manufacturing cost per gallon at approximately 1.33 cents for large refineries and 2.13 cents for smaller refineries. The American Petroleum Institute (L-7) indicated that modifying gasoline to have a Reid vapor pressure of 6 psi would increase manufactured costs by 1.24 cents per gallon. Assuming an average markup between refinery and consumer of about 100% (Oil and Gas Journal, December, 1972), the cost would average 2.5 cents per gallon more to the consumer. Assuming two years for a changeover (L-6), the change would become immediately effective throughout the Basin. Using the same gasoline consumption projections, the cost of the gasoline modification program comes to some $200 million per year.

In summary, the key considerations are:

- changing Reid vapor pressures results in substantial reductions in evaporative losses during fuel transfers
- a lower Reid vapor pressure may increase exhaust hydrocarbons negating some of the reductions gained
- a lower Reid vapor pressure may increase the reactivity of the gasoline again, partially negating some of the reductions gained
- the cost of such a program for the South Coast Basin is estimated at about $200 million per year.

In view of the above, changing the Reid vapor pressure of gasoline appears to be a strategy which deserves further investigation, but which cannot be recommended at this time.

Evaporative Emission Control - Service Station Modifications

A different approach to controlling evaporative losses from the filling of underground storage tanks is to use some type of vapor recovery or mechanical trap system. Trijonis (L-5) briefly describes such a setup consisting of a simple base attachment and vapor return system based on data provided by earlier APCD and A.D. Little reports.

Assuming a two year implementation schedule starting in 1973, the updated costs for a vapor recovery system are approximately $400 per storage tank and $1,000 per truck. The total capital investment for stations within the South Coast Air Basin by 1975 would be about $18.5 million. At 8% interest amortized over a 20 year lifetime for the system, the annual cost would be some $2 million to capture roughly 12,600 tons of evaporative emissions during the April-October months (approximately 60 tons/day), with lesser recoveries through the cooler remaining months of the year.

Recently, the American Petroleum Institute sponsored a study of methods available for evaporative emission control between the service station and the automobile. Of the techniques which primarily service station oriented "control methods would avoid about 71% of vapor emission immediately upon completion of the service station conversion. The vapor emission avoided would progressively increase over a period of about 10 years to about 94% to 98% depending on the particular method considered" (L-8). The variation in the percentage effectiveness over time is dependant upon the development of a safe, vapor tight filling nozzle and a matching standardized automotive fill pipe.

Although many alternatives are available, only three of the most promising techniques are presented. The descriptions and cost estimates for these methods are presented:

Case 3 - Vapor Displacement to Underground Storage with No Recovery of Excess Vapors

> This control scheme is based on displacing vapor from the vehicle fuel tank to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is a space around the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the undeground storage tank from which the fuel is pumped. The volume of the vapors displaced equals the volume of the fuel pumped from the storage tank. The vehicle fuel tank vapor in the underground storage tank is displaced back to the fuel supply truck at each delivery.... Any excess vapors generated at the service station due to temperature conditions is vented to the atmosphere (L-8).

Case 4 - Vapor Displacement to Underground Storage with Recovery of Excess Vapors by Refrigeration

> This control scheme is based on displacing vehicle fuel tank vapors during refueling back to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is a space around the nozzle

through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the underground storage tank from which the fuel was pumped. The volume of the vapor displaced equals the volume of the fuel pumped into the vehicle fuel tank. The vapor in the underground storage tanks is displaced back to the fuel supply truck at each delivery.... Any excess vapors generated at the service station due to temperature conditions are vented to a two-stage vapor compression system with intermediate cooling and final condensation by refrigeration. Condensed vapors consisting of propane and heavier hydrocarbons are returned to the underground storage tanks. The refrigeration unit is of 1.0 ton capacity at -10°F, and it is started and stopped on suction pressure sensing in a vapor holder (L-8).

Case 5 - Vapor Displacement to Underground Storage With Recovery of Excess Vapors by Activated Carbon Adsorption

This control scheme is based on displacing vehicle fuel tank vapors during refueling back to the storage tank from which the fuel was pumped. This is accomplished by making a tight seal at the interface between the fill nozzle and the fuel tank fill pipe. The fill nozzle is designed such that there is space in the nozzle through which the displaced vapors can be directed to a vapor return line. This line directs the vapors displaced from the vehicle fuel tank back to the underground storage tank from which the fuel was pumped. The volume of the vapors displaced equals the volume of the fuel pumped into the vehicle fuel tank.... Any excess vapors generated at the service station due to temperature conditions are vented to an activated carbon adsorption unit. All of the hydrocarbonds are adsorbed in this unit. The activated carbon unit consists of 4 transportable canisters containing 25 lbs. of activated carbon each. These canisters are regenerated about four times per month during the summer and considerably less during the rest of the year. The canisters are regenerated at the fuel supply terminal and their contained vapors are covered in the terminal vapor recovery system. The canisters are hauled to and from the supply terminal on trucks fitted specifically for this purpose (L-8).

The effectiveness of the "Case 3" method was approximated to be 71% recovery assuming service station conversions were initiated in 1975 and completed by 1977. Eventually, a 94% recovery could be expected when all automobiles were fitted with standarized fill pipes. This maximum control would not occur until about 1985 due to the lead time for normal attrition of older vehicles. Cases 4 and 5 are estimated to have about a 4% better vapor recovery (i.e., initially approximately 75% and ultimately approximately 98% by 1985.) The improved recoveries are due to the condensation or absorption of the vapors escaping from the storage tanks.

The costs of each case were estimated as follows:

Case 3 - Vapor Displacement to Underground Storage With No Recovery of Excess Vapors (L-8)

Capital Installed Cost Per Station

	Material	Labor*
Piping & Fittings (screwed)	$ 418	$1,438
(6) Tight fill nozzles at $37 each	222	48
	$ 640	$1,486
Contingency at 20% material, 10% labor	130	149
	$ 770	$1,635
Concrete removal & repair and tank purging	---	2,500
	$ 770	$4,135

New Station Cost = $770 + 1,630 = $2,400

Revamp Station Cost = $770 + $4,135 = $4,905

*Labor costs at $16/hour

Operating Costs to Service Station

Incremental additional replacement cost of nozzles and hoses at $36/year.

Case 4 - Vapor Displacement to Underground Storage With Recovery of Excess Vapors by Refrigeration (L-8)

Capital Installed Cost to Service Station

The capital costs show breakout for new and revamp stations.

Capital Installed Cost Per Station

	Material	Labor*
Piping & Fittings (screwed)	$ 833	$1,896
(6) Tight fill nozzles at $37 each	222	48
Condensation & Refrigeration Package Unit (Ref. 8)	5,000	64
	$6,105	$2,008
Contingency at 20% material 10% labor	1,195	195
	$7,300	$2,200
Concrete removal, repair, and tank purging	-----	2,500
	$7,300	$4,700

New Station Cost = $7,300 + $2,200 = $9,500

Revamp Station Cost = $7,300 + $4.700 = $12,000

*Labor costs at $16/hour

Operating Costs to Service Station

Incremental additional replacement cost of nozzles and hoses at $36/year.

Cooling water at 3 gpm at $0.20/M gallons, say $6/year.

Power supply for 3 HP motor at $0.30/KWH, say $11/year.

Maintenance and inspection cost, use 3%/year installed equipment cost = $7,100 x 0.03/year = $213/year.

Case 5 - Vapor Displacement of Underground Storage With Recovery of Excess Vapors by Activated Carbon Adsorption (L-8)

Capital Installed Cost Per Station

	Material	Labor*
Piping & Fittings (screwed)	$ 638	$2,096
(6) Tight fill nozzles at $37 each	222	48
(8) Carbon canisters at $80 each	640	32
Regeneration facilities at fueling terminal**	25	12
	$1,525	$2,188
Contingency at 20% materials, 10% labor	300	224
	$1,825	$4,912
Concrete removal, repair, and tank purging	-----	2,500
	$1,825	$4,912

New Station Cost = $1,825 + $2,412 = $4,237

Revamp Station Cost = $1,825 + $4,912 = $6,737

* Labor costs at $16/hour

** Regeneration facilities for 167 stations per each fueling terminal as follows:

	Material	Labor*
35 hookup point manifold	$1,500	$1,700
(1) vacuum pump (29" Hg.)	2,700	300
	$4,200	$2,000

Operating Costs to Service Station

Incremental additional replacement cost of nozzles and hose at $36/year.

Power supply for 5 HP motor at $0.03/KWH, say $17/year.

(1) laborer at fueling terminal at $10,000/year,

Operating Costs to Service Station, cont.

4 hours per day, for 167 stations.
($5,000/year)/(167 stations) = $30/year/station.
Truck hauling at $0.25 mile at 30,000 mile/year,
($0.25) (30,000)/(167) = $45/year/station.
Truck driver at $18,000/year for 167 stations,
($18,000/year/167 stations) = $108/year/station.
Assume operating costs at fueling terminal equal fuel recovery.

For the South Coast Air Basin in 1977, assume all future stations will require the installation of one of these methods upon construction and all others will be retrofitted. On this basis the approximate total costs for each method are given in Table L-2.

Table L-2

COSTS ASSOCIATED WITH VARIOUS VAPOR RECOVERY SYSTEMS
(South Coast Air Basin - 1977)

Case 3 - $ 25 Million
Case 4 - $178 Million
Case 5 - $ 72 Million

Annualized costs of a capital asset at 8 per cent with a twenty-year life is approximately 10 per cent of the capital expenditure. Under such a financing arrangement and including the estimated annual operating expenses, the costs and recoveries of the various systems are as follows (Table L-3):

Table L-3

ANNUALIZED COSTS FOR VAPOR RECOVERY SYSTEMS

	Cost/Year	Recovery in 1977 (Tons/Day)*
Case 3:	3 Million	~ 71 Tons/Day
Case 4:	21 Million	~ 75 Tons/Day
Case 5:	11 Million	~ 75 Tons/Day

* During the peak smog season -- April through October.

Using the projected increase of gasoline consumption, the recovery for each system after they achieve maximum effectiveness in 1985 is shown in Table L-4.

Table L-4

VAPOR RECOVERIES FROM VARIOUS SYSTEMS
(South Coast Air Basin - 1985)

	Recovery in 1985 (Tons/Day)*
Case 3:	90 Tons/Day
Case 4:	97 Tons/Day
Case 5:	97 Tons/Day

* April through October months.

On this basis, the relative cost-effectiveness ranking of the systems reviewed are:

1) Case 3 (lowest cost per ton of emissions recovered)
2) Case 5
3) Case 4 (highest cost per ton of emissions recovered)

Cases 4 and 5 offer additional recoveries but the incremental costs associated with these recoveries is very high. In light of these increased costs, it becomes very questionable whether such programs should be implemented.

Evaporative Emission Controls - Automobile Oriented Modifications

The American Petroleum Institute report (L-8) reviewed several possible automotive control systems which were capable of handling the evaporative emission from fuel tank refilling. The methods investigated included:

1) a collapsible bladder fuel tank
2) a flexible diaphragm tank
3) activated carbon system within the vehicle.

The activated carbon system looks promising with a cost-effectiveness ranking with the service station absorption system. It is, however, another control valve-orifice system with another system for the regeneration of the activated carbon and would probably require a nationwide change. This may lead to inspection and maintenance requirements for all vehicles. Retrofitting older cars is not considered practical, so total implementation would require 12 to 15 years. This system, as well as all others oriented either to the automobile or service station, will require the development of a vapor tight fill nozzle and a standardized automobile fill pipe. Some of the elements of the nozzle which must be considered in its development are (L-9):

1) Automatically provide a seal.
2) Interlocking nozzle valve to prevent opening until seal is in place.
3) Venting of vehicle tank back through nozzle and hose.
4) No significant increase of weight of safety nozzle.
5) Satisfy safety requirements with Underwriters Laboratories.
6) Limitations on tank pressurizations.
7) Prevention of blockage of return vapor line, i.e., splash-back or kinks in vapor line.
8) Automobile fuel tank vents differ. Some are vented by vent tube external to the fuel tank. Others are vented through the fill cap. In the first case, a large percentage will be displaced through the external vent tube.

The standardized fill pipe would constitute a total change for all automobile manufacturers. The change is, however, a relatively minor design requirement to place on manufacturers and will be required for any method of evaporative control which might later be necessary nationwide. The estimates of evaporative emissions used in the derivation of effectiveness of the API Case 3 control method should be verified in the field.

On January 17, 1972, The Board of Supervisors of the County of San Diego, acting as Directors of the San Diego County Air Pollution Control District, passed two new rules, 61 and 63 which will affect all service stations and associated support facilities. These two rules, quoted in part below, are designed to control the evaporative emission elements of concern. The counties in the South Coast Air Basin should adopt (if they have not already) regulations similar to the ones adopted by San Diego County.

(NOTE: The estimates of the evaporative losses made in this appendix were made independent of the estimates given by the Air Resources Board and consequently, differ from evaporative loss figures which appear in their emission inventory. The important point is not exactly how many tons are being emitted into the atmosphere but rather that these sources will be a significant air pollution problem by 1977 and that they can be effectively controlled.)

REGULATIONS ADOPTED BY THE SAN DIEGO COUNTY
AIR POLLUTION CONTROL DISTRICT
(January 17, 1972)

RULE 61. STORAGE OF VOLATILE ORGANIC COMPOUNDS. (a) A person shall not hold or store any volatile organic compound having a vapor pressure of 1.5 pounds per square inch absolute or greater, under actual storage conditions, in any stationary tank, reservoir or other container of more than 250 gallons capacity unless such tank, reservoir or other container is a pressure tank maintaining, at all times, working pressures sufficient to prevent hydrocarbon vapor or gas loss to the atmosphere, or is designed and equipped with one of the following vapor loss control devices or systems, properly installed, in good working order, and in operation:

(1) A floating roof, consisting of a pontoon type or double-deck type roof, or internal floating cover, resting on the surface of the liquid contents and equipped with a closure seal, or seals, to close the space between the roof edge and tank wall. (This control equipment is not appropriate if the volatile organic compound has a vapor pressure of 11 pounds per square inch absolute or greater under actual storage conditions.) All tank gauging and sampling devices shall be gas-tight except when gauging or sampling is taking place.

(2) A vapor collection and disposal system, consisting of a vapor gathering system capable of collecting the volatile organic compound vapors and gases discharged, and a vapor disposal system as prescribed in Rule 63. All tank gauging and sampling devices shall be gas-tight except when gauging or sampling is taking place.

(3) Other equipment of at least equal efficiency to the equipment specified in (1) and (2) above, provided plans for such equipment are submitted to and approved by the Air Pollution Control Officer

Pressure tanks required by this rule may be equipped with one-way automatic pressure relief valves necessary to meet any other requirements of law.

(b) Notwithstanding subdivision (a) of this rule, a person holding or storing the above specified compounds in a stationary tank, reservoir or other container of more than 250 gallons capacity which was either in existence on June 30, 1972, or in the process of being installed on said June 30, 1972, on the premises where they were to be used, shall not be subject to the provisions of subdivision (a) of this rule until January 1, 1974, provided, however, that such person is hereby required to file on or before July 1, 1972, a compliance schedule with the Air Pollution Control Officer showing how the person will bring his operations into compliance with subdivision (a) of this rule on or before said January 1, 1974. Failure to file such compliance schedule or abide by its terms shall render the prohibition contained in subdivision (a) of this rule immediately applicable to such person on July 1, 1972, or on the date of said person's failure to abide by said compliance schedule.

REGULATIONS ADOPTED BY THE SAN DIEGO COUNTY AIR POLLUTION CONTROL DISTRICT

(January 17, 1972)

RULE 63. VOLATILE ORGANIC COMPOUND LOADING FACILITIES.

(a) A person shall not load or allow the loading of volatile organic compounds having a vapor pressure of 1.5 pounds per square inch absolute or greater, under actual storage conditions, into any tank truck or trailer, railroad tank car, locomotive, aircraft, stationary storage tank with a capacity of more than 250 gallons, or boat or motor vehicle fuel tank having a capacity greater than 5 gallons from any loading facility unless such tank or loading facility is equipped with a vapor collection and disposal system, or its equivalent, properly installed, in good working order, and in operation. Loading shall be accomplished in such a manner that all displaced vapor and air will be vented only to the vapor disposal system. A means shall be provided to prevent liquid organic compound drainage from the loading device when it is removed from the hatch, or to accomplish complete drainage before such removal.

The vapor disposal portion of the system shall consist of one of the following:

(1) An absorber system or condensation system with a minimum recovery efficiency of 90 percent by weight of all the volatile organic compound vapors and gases entering such disposal system

(2) A vapor handling system which directs all vapors to a fuel gas system

(3) Other equipment of at least 90 percent efficiency, provided plans for such equipment are submitted to and approved by the Air Pollution Control Officer

Intermediate storage vessels may be used prior to disposal of vapors under 1, 2 or 3 above, provided they are so designed as to prevent release of vapors at any time during use.

(b) Notwithstanding subdivision (a) of this rule, a person loading or allowing the loading of the above specified compounds in the above specified storage vessels from the above specified loading facilities, either of which were in existence on June 30, 1972, or in the process of being installed for use on said June 30, 1972, shall not be subject to the provisions of subdivision (a) of this rule until January 1, 1974, provided, however, that such person is hereby required to file on or before July 1, 1972, a compliance schedule with the Air Pollution Control Officer showing how the person will bring his operation into compliance with subdivision (a) of this rule on or before January 1, 1974. Failure to file such compliance schedule or abide by its terms shall render the prohibition contained in subdivision (a) of this rule immediately applicable to such person on July 1, 1972, or on the date of said person's failure to abide by said compliance schedule.

References

L-1. California Air Resource Board, Los Angeles County Air Pollution Control District, Western Oil and Gas Association, Gasoline Modification -- Its Potential as an Air Pollution Control Measure in Los Angeles County, November, 1969.

L-2. Nelson, E. E., "Hydrocarbon Control for Los Angeles by Reducing Gasoline Volatility," presented at the International Automotive Engineering Congress, Detroit, Michigan, January 13-17, 1969.

L-3. Projections of gasoline consumption for the South Coast Air Basin; adapted from Branch, M. C. and E. Y. Leong (eds.), Research Investigation, Air Pollution and City Planning, Environmental Science and Engineering, University of California, Los Angeles, 1972, Appendix G.

L-4. California Air Resources Board, "Standards for Motor Vehicle Fuels," Subchapter 5, Section 2251, from Register 72, No. 31, July 29, 1972.

L-5. Trijonis, J. C., An Economic Air Pollution Control Model Application: Photochemical Smog in Los Angeles County in 1975, Ph.D. Thesis, California Institute of Technology, Pasadena, California, 1972.

L-6. "Statement on Cost of Changing Fuel Composition," November 10, 1969.

L-7. "Effect of Changing Gas Volatility on Refining Costs," Chemical Engineering Progress, 65(2):51-58 (1969).

L-8. Refinery Management Services Co., Motor Fuel Vapor Emission Control Study for American Petroleum Institute (Preliminary Draft Report), October, 1972.

L-9. "Control of Hydrocarbon Emissions from San Diego County Service Station," private communication from J. O. Dealy to S. T. Cuffe, July 27-28, 1972.

APPENDIX M

CONVERSION OF FLEET VEHICLES TO GASEOUS FUELS

History

In June, 1972, the City of Riverside sent a resolution to the Governor of California requesting he declare a "State of Emergency" in the South Coast Air Basin due to the air pollution. Concurrently, they submitted a plan which called for "the conversion of all vehicles in this basin to gaseous fuels which will reduce their emissions by 90% and will effect an 85% reduction in air pollution." (M-1) They further claimed, "Conversion to gaseous fuels is within our grasp. It relies upon present technology at minimal cost and inconvenience. The results of conversion programs of the type we propose have been tested and proven in the laboratory and in actual useage in everyday life".

On August 17 and 18, 1972, the ARB held public hearings to obtain information on the availability of gaseous fuels, conversion equipment, adequacy of existing fuel distribution facilities, etc. Their conclusion was, "The evidence given at the hearing showed that implementation of the entire Riverside proposal is not feasible. However, conversion of some fraction of the Basin's motor vehicle population is possible".(M-2)

In a later release(M-13), the Air Resources Board concluded that it might be possible to convert approximately 275,000 vehicles to LPG and CNG. This conversion program would be dependent on refinery modifications to increase the LPG supply and a diversion of natural gas from power plant users. The ARB summary also pointed out the necessity to complete the gaseous fuel conversion program within two years in order to achieve a significant impact from the emission reductions.

Thus, conversion of fleet vehicles to gaseous fuels is a practical air pollution strategy which the State of California has investigated. This Appendix covers various aspects of conversion to gaseous fuels including supply, distribution, availability of certified equipment, maintenance, insurance, reactivity, costs, legal problems and constraints. The conclusions and recommendations of the report have been based on these discussions as well as practical considerations.

Introduction

Presently, the conversion of vehicles to burn gaseous fuels is most applicable to fleet vehicles because of problems encountered in fuel availability. Fleet operators generally buy fuel in bulk and can afford to have the special equipment to store and handle gaseous fuels. In addition, fleet operators frequently have their own garages and mechanics available for the proper maintenance of the fleet vehicles. In terms of costs, conversions are an economic trade-off between lower fuel and maintenance costs versus a high initial capital outlay. To date, the majority of conversions to gaseous fuels have been justified primarily on the economic benefits derived from such conversions. The air pollution reductions have been an added bonus. Depending on the mileage driven, the capital costs for most conversions can be recovered in two to five years.

Gaseous fuels are cleaner burning than gasoline due to their lower molecular weight and carbon content; they ignite more rapidly and combustion proceeds more nearly to completion. Usually, the combustion products of gaseous fuels are less reactive in forming photochemical smog.

Modification to gaseous fuels is considered a fairly simple, straightforward operation requiring the installation of a carburetor, fuel tanks, pressure regulating devices, shut-off valves and fuel lines. The cost ranges from around $350 to $500.

Gasoline is liquid at room temperature and pressure. Liquified petroleum gas (LPG) is liquified at a pressure of about 125 psi and room temperature. Natural gas cannot be liquified at normal temperatures. When it becomes a liquid at -278°F and high pressures, it is called liquified natural gas (LNG). Natural gas is normally stored under pressure and termed compressed natural gas (CNG).

Currently, only CNG and LPG conversions have been seriously marketed. In terms of implementing short range strategies, only CNG and LPG are considered in the present analysis.

Compressed Natural Gas (CNG)

Natural gas is primarily methane. It is compressed to high pressures (1,000 - 2,000 psi), and stored in high pressure fuel tanks. This necessitates a compressor at the refueling stations. Natural gas is relatively safe (odorants are available and should be added), although the high pressures used require leak-free fuel lines and fittings. The typical travel range of CNG vehicles is 70 miles. By sacrificing more storage space for additional fuel tanks, the range can be extended.

Liquified Petroleum Gas (LPG)

LPG is a mixture of propane and butane with vapor pressures ranging from 100 to 300 psi at normal temperatures. It is transported in liquid form and transferred to pressure storage tanks. LPG is also relatively safe (odorants are available and should be added), and handling procedures are well established. The typical travel range of LPG vehicles is 220 miles.

Supply

The supply of CNG and LPG for the South Coast Air Basin requires considerations of present firm demands, fluctuations in demand during the summer and winter months, needs and requirements of power plants, present supply, possibilities for augmentation; diverting a portion of the present demands to fleet vehicles requires an investigation of the advantages of switching from power plants to fleets and also the costs associated with modifying some of the refinery processes.

The Pace Company report concludes that supplies of CNG and LPG are adequate to replace up to 33 per cent of the gasoline consumed in the Basin provided the combination consists of 25 per cent CNG and 8 per cent LPG.

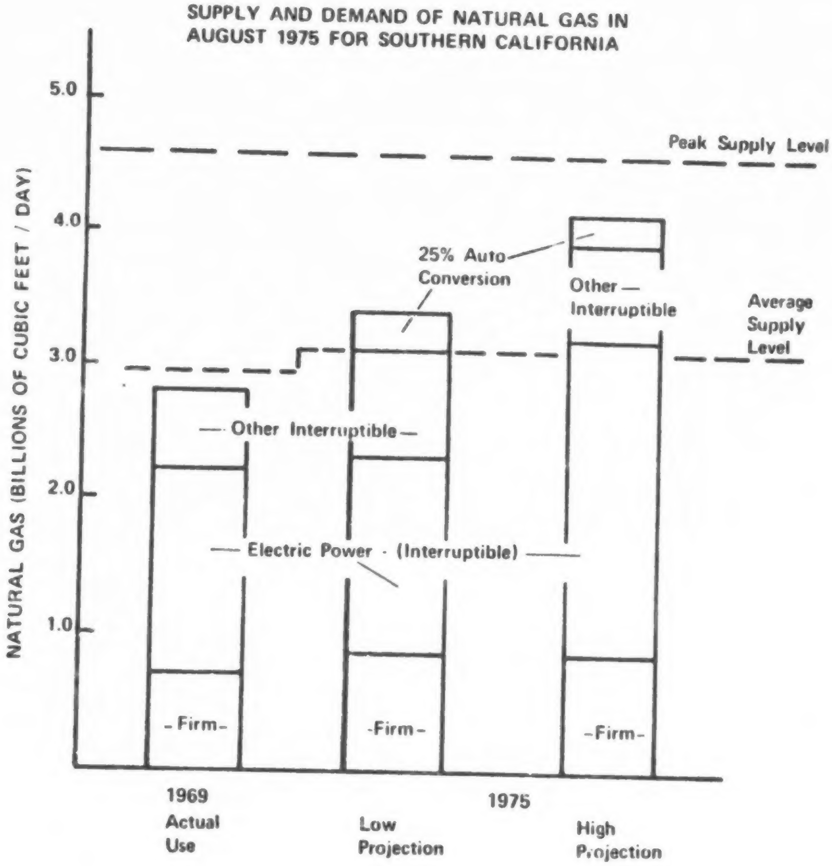
A 25 per cent conversion to CNG is equivalent to 250 million cubic feet per day. Figure M-1 shows firm demand for natural gas during the summer months is around 600 million cubic feet per day. This leaves about 2 billion cubic feet per day as the interruptable supply which would have to be diverted from power plants and industrial users in order to supply this need to motor vehicles.

An 8 per cent conversion to LPG is equivalent to about 10 million barrels per year, which was the total consumption of LPG in California in 1970 (Figure M-2) The supply of LPG is increasing rapidly and projected requirements for fleet vehicles would not place a great strain on refineries and other sources.

CNG Supply

The relatively small amount of natural gas needed for the conversion cited above, 250 million cubic feet per day, can be taken from "interruptible' users and would not affect the firm customers. Such a diversion can be accomplished at a reasonable price.

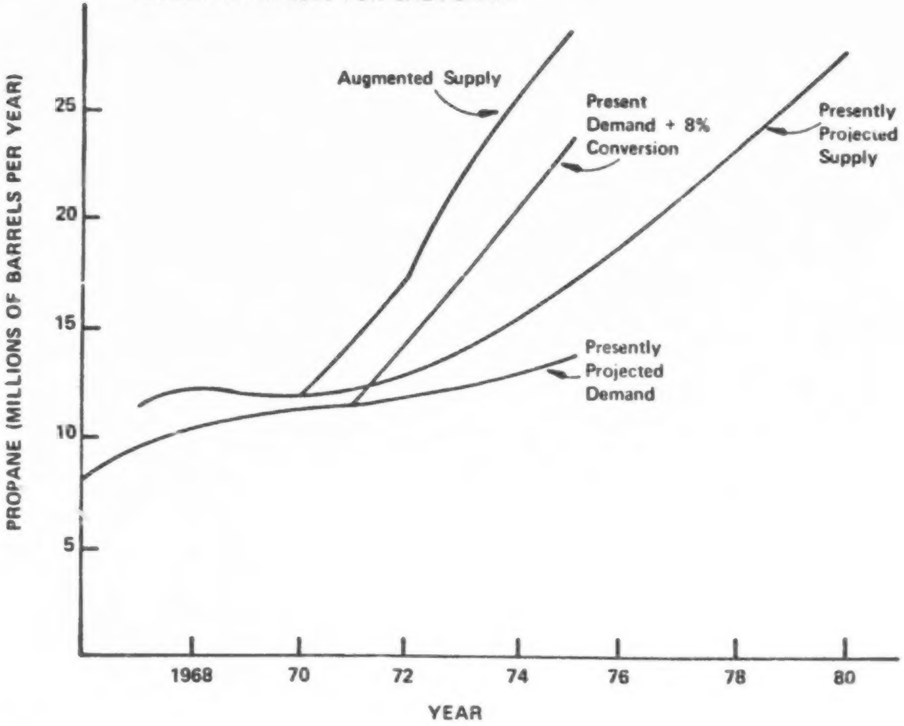
Figure M-1



Source: See Reference M-4, p. 142.

Figure M-2

SUMMARY OF PROPANE SUPPLY AND DEMAND
ANNUAL AVERAGES FOR CALIFORNIA



Source: See Reference M-4, p. 143.

Dr. List concludes that the use of natural gas in motor vehicles "results in emission reduction more than ten times greater per kilowatt hour of energy produced than the use of the gas in place of residual crude in industrial and power plant boilers".(M-5) Long flame residence times in power plant furnaces permit the use of gasoline as a fuel with substantially reduced hydrocarbon and carbon monoxide emissions when compared to vehicle use of gasoline.

Figure M-3 illustrates the natural gas supply and demand situation for the winter months. During this period the "firm" demand is considerably higher. During these months it would be difficult to divert natural gas into fleet vehicle uses. Hence, converted vehicles should probably be equipped with dual-fuel systems. In view of the seasonal nature of maximum oxidant pollution, this appears to be a reasonable option. Of primary concern is the use of cleaner burning fuels during the summer season.

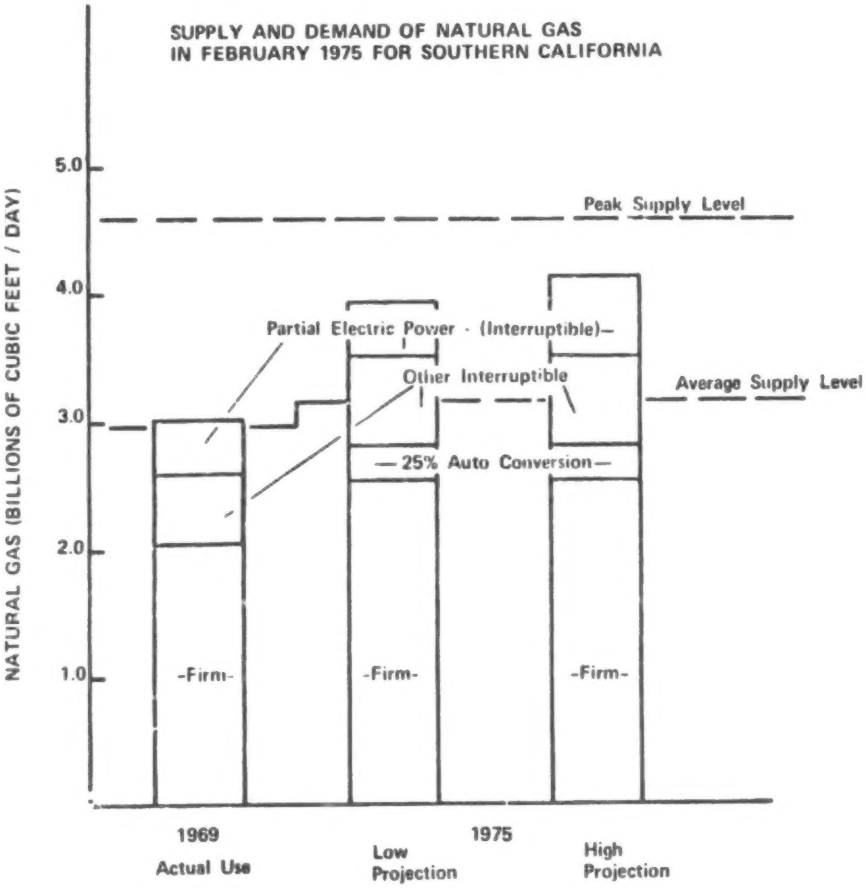
This estimate is somewhat lower than the previous estimate but still shows the potential supply for meeting the demands for several hundred thousand fleet vehicles.

LPG Supply

The existing market for LPG in South Coast Air Basin is small relative to CNG. As seen in Figure M-3, an 8 per cent conversion of gasoline to LPG involves doubling the supply from 12.5 million barrels a year in 1971 to 26.1 million barrels by 1975. On a national scale the supply of LPG is projected to increase by 27% in 1975(M-3). The shortage of LPG supply in California by 1975, due in part to conversions of fleet vehicles, could conceivably be made up by attracting additional suppliers from California refineries and field producers or from producers in heavy surplus areas such as west Texas, the Rocky Mountain region, and Western

Canada. Current consumption of LPG in the South Coast Air Basin is about 600 million gal. (14 million barrels) per year, of which 50 million gal. (1.2 million barrels) are used as vehicle fuel.

Figure M-3



Source: See Reference M-4, p. 162

Distribution

Present distribution facilities for CNG and LPG are inadequate to handle a large increase in gaseous fueled vehicles. Given the demand for such facilities, however, a large number of these facilities could become available in a relatively short time period. Commercial fleets using CNG would very likely have their own fueling facility. Since natural gas is readily available in the South Coast Air Basin, the only requirement for a fueling facility is a compressor and storage tank. Every service station is a potential outlet for LPG. At present, LPG is available at about 64 stations in the Los Angeles area; its distribution poses much less of a problem. Once the market is developed sufficiently, it should not be difficult to recover the capital costs of the tank and dispensing equipment. Here again, commercial fleets could have their own fueling facility.

Conversion Equipment

There are a number of companies which manufacture and/or distribute CNG or LPG conversion equipment. Estimates of production capabilities for the type of equipment seem to indicate several hundred thousand fleet vehicles could be converted to run on CNG or LPG within a period of two years. The maximum benefit to be derived from a conversion program is obtained from the earliest possible implementation time schedule. Since newer, more controlled vehicles are constantly entering the market, air quality improvements from conversion to gaseous fuel decrease with the simple passage of time.

Dual Fuel Systems, a subsidiary of Pacific Lighting, produces CNG conversion equipment. Given sufficient demand, they have stated that they could produce 100,000 carburetors per year The limiting factor in a massive conversion program appears to be the present manufacturers' capabilities for high pressure tanks, which is approximately 36,000 per year. LPG carburetors are currently produced at the rate of 18,000 per year. The present production LPG fuel tanks for motor vehicles is around 24,000 tanks per year.(M-2) Here again, the limiting factor would be the production and supply of LPG fuel tanks.

A frequently asked question is why the major auto manufacturers do not produce cars with dual fuel systems or gaseous fuel systems. Detroit has expressed its inability to manufacture these 1973 and 1974 model vehicles because of the lead time requirements for making engine and body modifications (estimated at about two years minimum). The limited demand is certainly an equally important consideration.

California presently exempts vehicles using gaseous fuels from the fuel tax if the conversion equipment installed is approved by the Air Resources Board (ARB). The ARB approves all fuel conversion systems which meet or exceed the 1974 California emission standards. As of July 10, 1972, the following systems were approved for tax-free use of CNG or LPG. Figures M-4 through M-6 show several typical conversion systems.

Table M-1

Gaseous Fuel Conversion Systems
Approved for Tax Free Use
By the Air Resources Board

(The following systems are approved for all gasoline motor vehicles)

1. Impco - Liquefied Petroleum Gas and Dual Fuel (LPG or Gasoline)

Impco Carburetor Model	Engine Size Class	Engine Size Displacement Cubic Inches
CA-100 (with or without turbocharger)	B,C	140 through 250
CA-125	A through E	0 through 375
CA-225	B through F	140 and over
CA-425	E,F	300 and over
CA-300A (LPG plus supercharger)	A	under140
CA-300A (Dual Fuel-LPG or Gasoline)	A through F	All

CAG-225 and CAG 425 are governed versions of CA225 and CA425 and are acceptable.

Natural Gas (Dual fuel - natural gas or gasoline)

CA-300 AN (Dual fuel)	E	300 through 375

2. Marvel - Schebler - Liquefied Petroleum Gas

Century Carburetor Model	Engine Size Class	Engine Size Displacement Cubic Inches
3C-705-LE	A,B	0 through 200
3C-706-LE	A	under 140
3C-706-LE	C,D	250 through 300
3C-705-DTLE	D through F	250 and over
3C-706-DTLE	E,F	300 and over

Imperial 300-same as CA300A. The 3CG prefix is the governed version of the 3C prefix and is acceptable.

3. San Diego Gas & Electric - Natural Gas

Impco Carburetor Model	Engine Size Class	Engine Size Displacement Cubic Inches
CA-125	A through C	0 through 250
CA-225	D,E	250 through 375

Table M-1 (Continued)

4. Dual Fuel - Natural Gas plus Gasoline (Dual Fuel)

Carburetor Model	Engine Size Classes	Engine Sizes-Cubic Inches
1.25	A through F	All

5. Algas Industries - Liquefied Petroleum Gas

Carburetor Model	Engine Size Classes	Engine Sizes-Cubic Inches
PCA 500C	E,F	300 and over

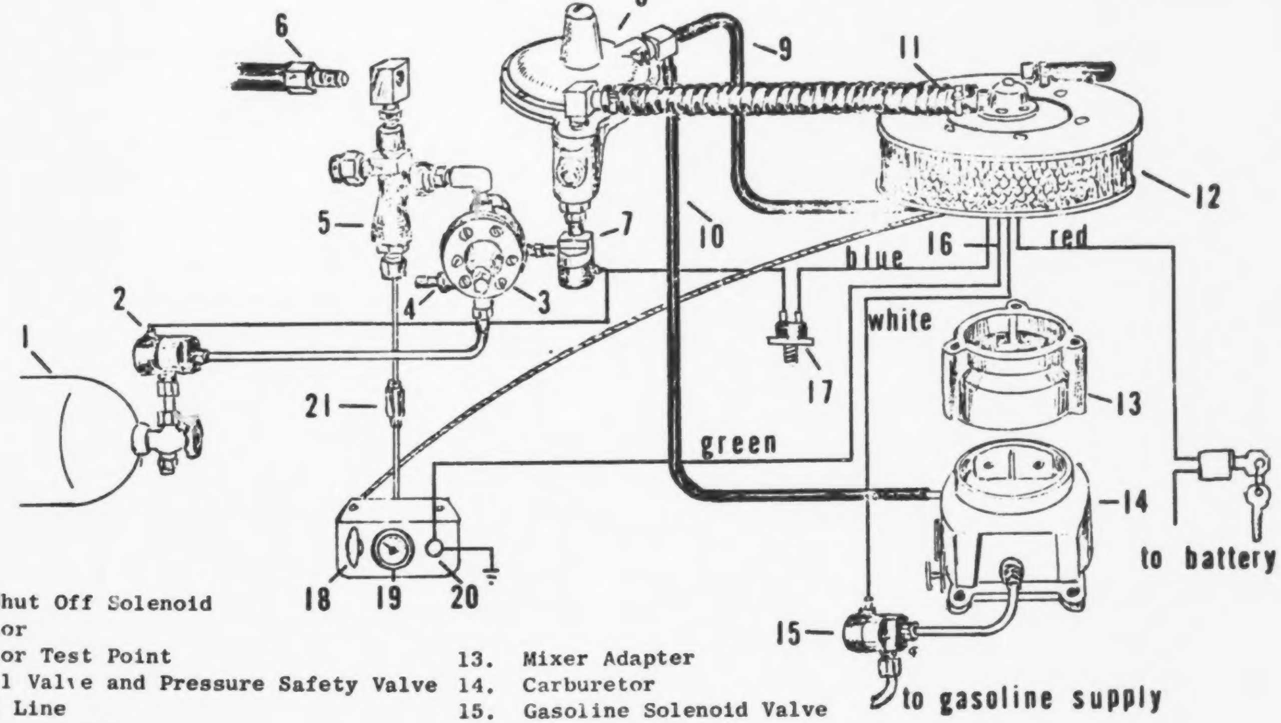
6. Beam - Liquefied Petroleum Gas

Carburetor Model	Engine Size Classes	Engine Sizes-Cubic Inches
5C-100	B	300 through 375
5C-200	E,F	300 and over

7. Pneumetrics - Natural Gas (Dual Fuel)

Carburetor Model	Engine Size Classes	Engine Sizes-Cubic Inches
Imperial 300 AN	E	300 through 375

Figure M-4 **DUAL FUEL SYSTEMS, INC.**
Compressed Natural Gas System Schematic


1
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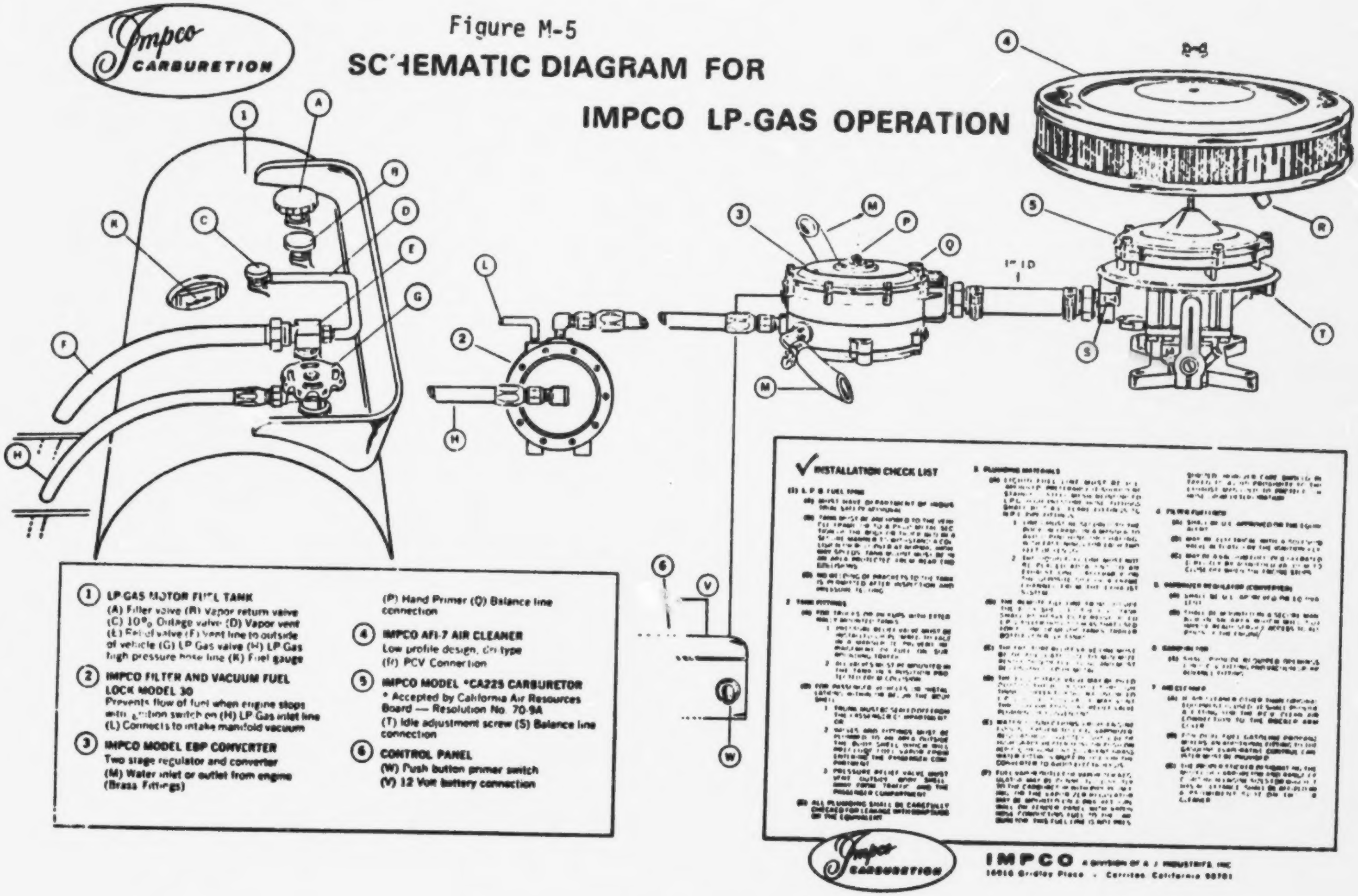
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
red
blue
white
green
to battery
to gasoline supply

1. Fuel Cylinder
2. Positive Fuel Shut Off Solenoid
3. Primary Regulator
4. Primary Regulator Test Point
5. Natural Gas Fill Valve and Pressure Safety Valve
6. Cylinder Refill Line
7. Natural Gas Solenoid Valve
8. Secondary Regulator
9. Secondary Regulator Vent Line
10. Accelerator Vacuum Line
11. Vapor Hose
12. Dual Fuel Systems Gas Air Mixer
13. Mixer Adapter
14. Carburetor
15. Gasoline Solenoid Valve
16. Wiring Harness
17. Vacuum Switch
18. Fuel Selector
19. Natural Gas Gauge
20. Fuel Selector Indicator Light
21. Fuel Pressure Safety Restrictor Fitting

Source: See Reference M-12.

Figure M-5

SCHEMATIC DIAGRAM FOR IMPCO LP-GAS OPERATION


Impco CARBURETION
1
A
B
C
D
E
F
G
H
K
L
2
H
3
M
P
Q
1" I.D.
4
5
R
S
T
6
V
W
① LP-GAS MOTOR FUEL TANK
(A) Filler valve (B) Vapor return valve
(C) 10% Outage valve (D) Vapor vent
(E) Relief valve (F) Vent line to outside of vehicle (G) LP Gas valve (H) LP Gas high pressure hose line (K) Fuel gauge
② IMPCO FILTER AND VACUUM FUEL LOCK MODEL 30
Prevents flow of fuel when engine stops with ignition switch on (H) LP Gas inlet line
(L) Connects to intake manifold vacuum
③ IMPCO MODEL EBP CONVERTER
Two stage regulator and converter
(M) Water inlet or outlet from engine (Brass Fittings)
(P) Hand Primer (Q) Balance line connection
④ IMPCO AFI-7 AIR CLEANER
Low profile design, dry type
(R) PCV Connection
⑤ IMPCO MODEL *CA225 CARBURETOR
* Accepted by California Air Resources Board — Resolution No. 70-9A
(T) Idle adjustment screw (S) Balance line connection
⑥ CONTROL PANEL
(W) Push button primer switch
(V) 12 Volt battery connection
✓ INSTALLATION CHECK LIST
Impco CARBURETION
IMPCO A DIVISION OF A. J. INDUSTRIES, INC
16010 Gridley Place · Cerritos California 90701

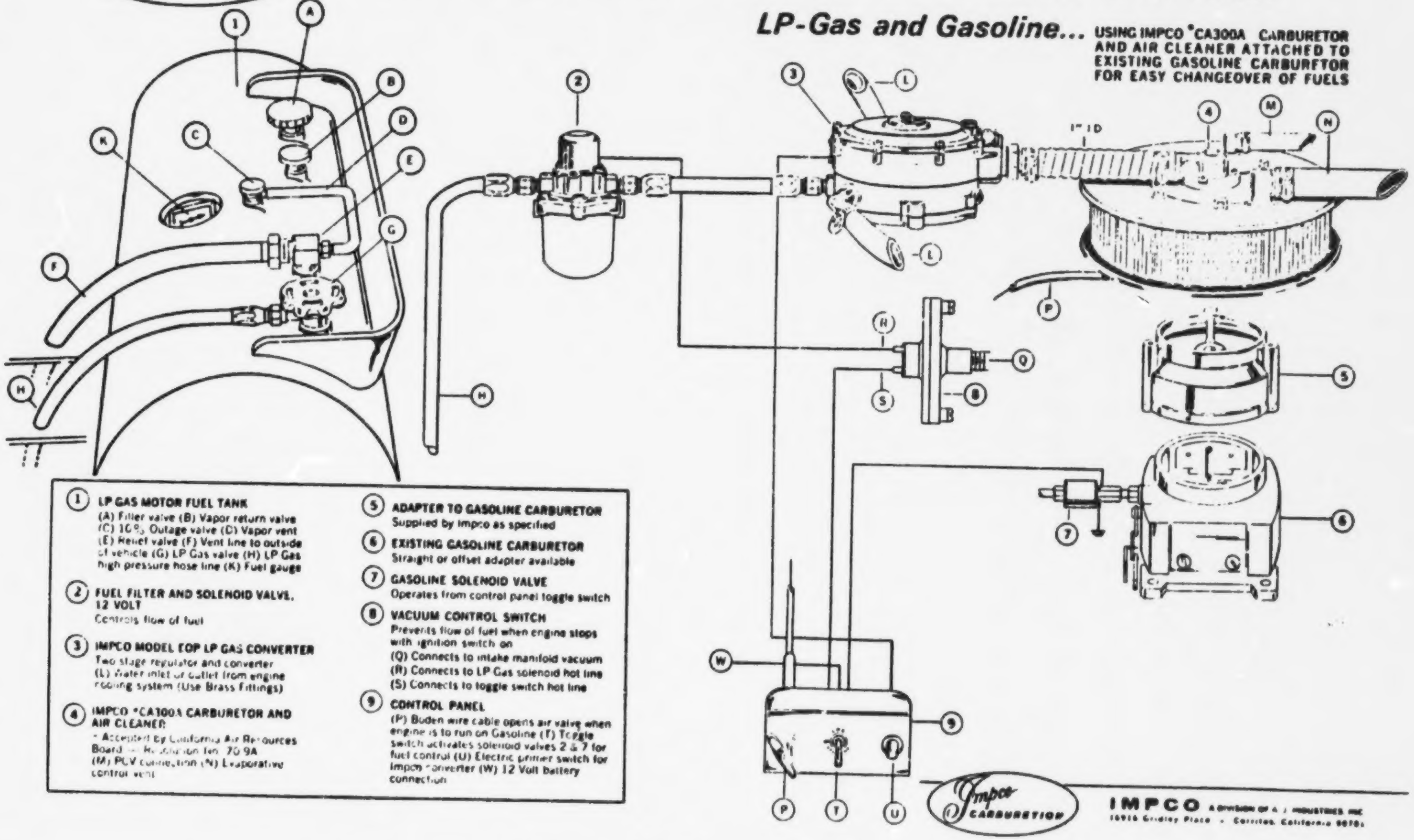
Source: See Reference M-12

Impco CARBURETION

Figure M-6

SCHEMATIC DIAGRAM FOR IMPCO DUAL FUEL OPERATION

LP-Gas and Gasoline... **USING IMPCO *CA300A CARBURETOR AND AIR CLEANER ATTACHED TO EXISTING GASOLINE CARBURETOR FOR EASY CHANGEOVER OF FUELS**



① **LP GAS MOTOR FUEL TANK**
(A) Filler valve (B) Vapor return valve (C) 10% Outage valve (D) Vapor vent (E) Relief valve (F) Vent line to outside of vehicle (G) LP Gas valve (H) LP Gas high pressure hose line (K) Fuel gauge

② **FUEL FILTER AND SOLENOID VALVE, 12 VOLT**
Controls flow of fuel

③ **IMPCO MODEL EOP LP GAS CONVERTER**
Two stage regulator and converter
(L) Water inlet or outlet from engine cooling system (Use Brass Fittings)

④ **IMPCO *CA300A CARBURETOR AND AIR CLEANER**
* Accepted by California Air Resources Board — Resolution No. 70 9A
(M) PCV connection (N) Evaporative control vent

⑤ **ADAPTER TO GASOLINE CARBURETOR**
Supplied by Impco as specified

⑥ **EXISTING GASOLINE CARBURETOR**
Straight or offset adapter available

⑦ **GASOLINE SOLENOID VALVE**
Operates from control panel toggle switch

⑧ **VACUUM CONTROL SWITCH**
Prevents flow of fuel when engine stops with ignition switch on
(Q) Connects to intake manifold vacuum
(R) Connects to LP Gas solenoid hot line
(S) Connects to toggle switch hot line

⑨ **CONTROL PANEL**
(P) Boden wire cable opens air valve when engine is to run on Gasoline (T) Toggle switch activates solenoid valves 2 & 7 for fuel control (U) Electric primer switch for Impco converter (W) 12 Volt battery connection

Impco CARBURETION

IMPCO A DIVISION OF A. J. INDUSTRIES, INC
16916 Gridley Place • Cerritos, California 90701

Source: See Reference M-12

Maintenance

Gaseous fuels do not cause deposits in the engine and fuel system thereby extending the time between oil and filter changes and tune-ups. Engine life is generally increased. There is no need for a choke and the engine starts up reasonably quick even at low temperatures. Unlike vehicles fitted with add-on equipment, the gaseous fueled vehicles do not require emission checking, replacement of reactors, cleaning of emission control valves, etc. However, they do require proper tuning to maintain their low-emission characteristics.

The General Services Administration's report on their Sawtelle Fleet gives the following cost figures for use of CNG (Table M-2). The GSA is involved in an ongoing program to test conversion to gaseous fuels; they are currently in the midst of evaluating results from 1200 of their fleet vehicles.

Table M-2

Report of the GSA Sawtelle Fleet Experience

		Maintenance		Cents Per Mile	
Automobiles	Miles	Vehicle Total	Routine[a]	Vehicle Total	Routine[a]
Gas	60,960	$1,193	$169	1.96	0.28
CNG	62,835	1,529	156	2.43	0.25
Light Trucks					
Gas	30,869	514	156	1.66	0.50
CNG	21,388	247	44	1.15	0.20
Medium Trucks					
Gas	14,140	1,296	109	9.17	0.77
CNG	17,684	911	62	5.15	0.35

[a] Routine maintenance includes, Oil, Oil Filters & Tuneups

Source: See Reference M-6

Fleets using LPG have several similar cost savings. To date, comprehensive data has not been generated. However, the police fleet at Chandler, Arizona had the following figures for routine maintenance tests: 0.511 cents/mile for gasoline and 0.13 cents/mile for LPG. The sample size was two cars each.

Safety

Several properties inherent in gaseous fuel systems make them as safe as present motor vehicle systems. The EPA position paper on gaseous fuel conversion states, "Enough experience has now been accumulated with gaseous fuel vehicles to demonstrate that under closely controlled fleet-operation, the fuels can be used safely."(M-7) Gaseous fueled vehicles, when used in strict compliance with applicable standards and regulations, and maintained by qualified repairmen are as safe as conventional gasoline powered automobiles. The lower flash point of gaseous fuels and sturdy construction of storage tanks, makes fire accidents very infrequent.

Gas leaks in enclosed spaces are the principal fire hazard associated with gaseous fuels. Natural gas rises and dissipates as a vapor unless it is confined.. Both CNG and LPG contain odorizers which reveal their presence in the event of a leak.

R. H. Eshelman, Detroit Technical editor for automotive industries recently wrote, "Evidence from many fleet type operations to date suggest LPG fuel systems may prove as safe or safer than conventional ones".(M-8) The General Services Administration (GSA) recently tested a fleet of dual-fuel vehicles using gasoline and CNG. The GSA report stated "The first year's experience with these dual-fuel vehicles has resulted in an enviable safety record. None of the data studies, or the people consulted indicates any safety problem when these vehicles were used under normal conditions..."(M-6)

Insurance

The insurance companies do not distinguish between gaseous fueled vehicles and gasoline powered vehicles in their rate structures. Their only requirement is that conversions meet applicable standards. A common standard is "National Fire Protection Association Standard No. 58-Storage and Handling of Liquid Petroleum Gases".(M-9) Gaseous fuel conversions in the city must meet the strict standards laid down by the Los Angeles City Fire Department.

The insurance industry underwrites both policies but differentiates between gaseous fuels and gasoline refueling stations, as well as parking garages, in their rate structure.

Fleet operators have not encountered any difficulty in insuring their LPG fueled vehicles at normal rates. At present, some difficulties may be encountered in insuring CNG fueled vehicles since no standard procedure has been established by the insurance companies for insuring these vehicles.

The following are some of the national companies which insure gaseous fueled vehicles:

- Allstate Insurance Company
- Lumbermens Mutual Casualty Company
- Insurance Company of North America
- Hartford Insurance Group

Driver Reaction

According to General Services Administration's report(M-10), the driver acceptance of gaseous fueled vehicles is very good. While driving in heavy smog areas, drivers take pride in operating a vehicle conspicuously identified as running on a clean-burning, low polluting fuel. There is considerable dedication to the program and its objectives

Continued driver acceptance requires that components have high reliability. Problem areas include leaks, misfiring, missing controls or inconspicuous identification on control panels. Drivers did not detect a performance loss in well-tuned gaseous fueled vehicles.

In the South Coast Air Basin fleet owners are well organized in various associations, and their ability to forestall regulation is significant. The Yellow Taxi Cab association of L.A. has already registered public opposition to any mandatory program of conversion to gaseous fuels.

Experience from other government regulation indicates that industry resistance would be expressed in many forms. They may use "expert witnesses" or special studies to prove that regulations would be so cumbersome as to be impractical. They may prolong public hearings by raising new issues, each time. Or they will wait for all public proceedings to be completed and then file for a court injunction.

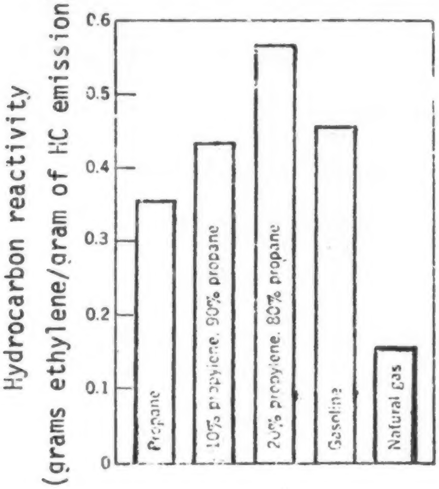
Reactivity

The reactivity of hydrocarbons emitted by gaseous fueled vehicles is considerably less than from gasoline fueled vehicles. The EPA positions paper states that "Gaseous fuels have an additional advantage over a gasoline fuel in the form of significantly less photochemical reactivity of the hydrocarbons in the exhaust gases. Natural gas consists primarily of methane and produces less reactive exhaust gases than does LPG which is largely composed of propane".(M-7)

Exhaust hydrocarbon emissions from CNG fueled vehicles are composed of methane and ethane. These compounds are less reactive compared to the olefinic and aromatic compounds of burned gasoline in producing photochemical smog. Methods of evaluating reactivity of the hydrocarbon are under development. The California Air Resources Board adopted on November 19, 1972, a reactivity factor, R = 0.5 for natural gas emission data as an interim measure.(M-6) This means measured hydrocarbon values from gaseous fueled vehicles must be multiplied by a factor of 0.5 to arrive at their corrected "photochemical potential".

Figure M-7 compares the reactivity of exhaust produced from propane/propylene mixtures to gasoline and natural gas. Even though the absolute reactivity of the 20 per cent propylene and 80 per cent propane is higher than gasoline, when combined with the total mass HC emissions, the reactivity of the mixture is lower than gasoline.

Figure M-7
Reactivity of exhaust produced from propane/propylene mixtures compared to gasoline and natural gas



Source: See Reference M-11

Time Limitations

Detroit presently limits the engine warranty on vehicles converted to operate on gaseous fuels. Since production models after 1975 are expected to have emission levels substantially lower than vehicles converted to operate on gaseous fuels, engine manufacturers are not ready to make adjustments which would optimize existing engines for gaseous fuel operation.

The EPA position paper states that, "Because future gasoline powered vehicles (1976) will have lower emissions than current vehicles converted to operate on gaseous fuels, after 1974 an accelerated program of vehicle replacement would be more efficient in reducing emissions from State vehicles than a large gaseous fuel conversion program". Thus any conversion to gaseous fuel programs should be implemented as soon as possible to derive the maximum air quality improvements.

Some Constraints

Due to absence of lead in LPG, valve recession has been experienced. Vehicles used for long distances at high speeds would need hardened valve seats. In general, fleet vehicles should not develop this problem because of the short range distances they usually drive.

CNG has serious range limitations, and could be a constraint for certain fleet operations. Also CNG tanks weigh 40 pounds for each gallon equivalent of fuel.

Even though gaseous fueled vehicles may be safer than gasoline vehicles when all pertinent codes and regulations are adhered to, they are "new" and hence, subject to restrictive safety regulations. Public reaction, lower costs and reliability should more than compensate for the various disadvantages mentioned above.

Costs

Costs for conversion to fleet-owners can be divided into two categories: (1) capital costs for vehicle conversion (fuel tanks and liners, carburetors, etc.) and fueling stations, (2) changes in current operational procedures including new maintenance techniques, fueling patterns, etc.

Benefits from conversion include longer engine component life, less maintenance costs, lower fuel costs (as long as state tax exemption is enforced) and significantly lower pollutant emissions.

Costs of equipment and installation to burn CNG or LPG is around $350-500. CNG fuel compressors cost in excess of $10,000. Storage facilities for LPG at fueling stations cost approximately $3200 per tank. Experience to date indicates savings in maintenance costs. It is imperative, however, that gaseous fueled vehicles be properly maintained to achieve their low emission characteristics.

Recovery of capital expenditures, involved in fleet conversion to gaseous fuels, depends on the fleet size and mileage travelled. New cars converted to burn gaseous fuels have 'limited' manufacturer's warranty. Small fleet operators may not have the financial capability to install CNG fueling facilities.

Most fleet owners purchase new cars each year and may resist spending considerable sums of money for the interim period till 1976. There is no Federal tax on natural gas and a 7¢/100 cubic feet California State tax. Again, exemptions from state tax are available for CARB approved systems. There is a 4¢/gal Federal tax on LPG and a 6¢/gal California State tax. Exemptions from the state tax are available for CARB approved systems.

If the fleet vehicles are driven sufficient distances each day, the cost savings are sufficient to justify conversion to gaseous fuels. Each fleet will experience a different set of costs for conversion and different amount of savings; the economics of converting fleet vehicles has to be studied on an individual basis.

Range of costs for conversion of each fleet car is as follows:[4]

	CNG	LPG
Equipment	$300	$300
Fuel tankage	$20-40 per gallon	$3.50-10 per gallon
Installation	$100-300	$100-300

Cost per 100 cubic feet for CNG are as follows:(2)

NG cost	6-8¢/100 std. cubic feet
Compressing costs	3-4¢/100 std. cubic feet
State tax	7¢/100 std. cubic feet

Assuming 15 miles per 100 standard cubic feet of NG, estimated costs for fleets is 9-12¢ without tax and 16-19¢ with tax, for 100 SCF of natural gas (100 SCF of NG is assumed equivalent to 1 gallon of gasoline).

LPG retails for 13-20¢ per gal without tax. Costs for fleet vehicles per equivalent gallon of gasoline is 15¢ without tax and 25¢ with tax.

References

M-1. City of Riverside, California, Air Pollution Smog - An Existing Health Hazard, An Imminent Disaster, Office of Disaster Preparedness, June 1972 (A resolution, report and proposed emergency plan from the Mayor and Council of the City of Riverside to the Governor of the State of California).

M-2. State of California, The Resources Agency, Air Resources Board, "Summary of Hearings on the Feasibility of Converting Gasoline Powered Vehicles in the South Coast Air Basin to Gaseous Fuels", August 17-18, 1972.

M-3. The Pace Company, Evaluation of Gaseous Fuels Supply for Motor Vehicle Usage in the Los Angeles Basin, prepared for the EQL-Caltech, February 15, 1971.

M-4. Lees, L., et. al., Smog: A Report to the People, Environmental Quality Laboratory, California Institute of Technology, 1972.

M-5. List, E. J., "Energy and the Environment in Southern California", California Institute of Technology, 1971.

M-6. "Pollution Reduction with Cost Savings- A Report on the General Services Administration's Dual Fuel Experiment", U.S. Government Printing Office, Washington, D. C., 1971.

M-7. Environmental Protection Agency, "Conversion of Motor Vehicles to Gaseous Fuel to Reduce Air Pollution", (position Paper), 1972.

M-8. Eshelman,R.H., "LP-Gas Conversion", Automotive Industries, May 15, 1970.

M-9. NFPA No. 58, copies available from the National Fire Protection Association (60 Battlerymarch Street, Boston, Mass. 02110).

M-10. Foote, W. B., "Compressed Natural Gas Experience", presented at the GSA Sponsored Symposium, Gaseous Fueled Vehicles and the Environment, Washington, D. C., May 24-26, 1972.

M-11. Fleming, R. D., et. al., "Propane as an Engine Fuel for Clean Air Requirements", Journal of the Air Pollution Control Association, 22(6): 455 (1972).

M-12. Environmental Quality Laboratory - California Institute of Technology, Caltech Clean Air Car Project Gaseous Fuels Manual, November 1, 1971.

M-13. Air Resources Board Informational Release, "Item: Control Measures for Reducing Photochemical Air Pollution in the South Coast Air Basin, including the Proposal by the City of Riverside to Convert Vehicles to Gaseous Fuels", September 12-13, 1972.

APPENDIX N

EMISSION INVENTORY REVISION - EPA (DECEMBER 1972)

This appendix presents a portion of the California emission inventory revision compiled by EPA personnel with assistance from the Air Resources Board staff. The modifications deal primarily with motor vehicle emission contributions for 1970 and 1977 in the South Coast Air Basin. Section I briefly explains the EPA rationale for the determination of a maximum allowable emission level required to achieve the photochemical oxidant standard.

I. Determination of Maximum Allowable High Reactive Hydrocarbon Emissions to Meet .08 ppm 1-hour Oxidant Standard

The oxidant control strategy discussed in this report involves the control of high reactive organic gases (hydrocarbons) as defined by the Los Angeles APCD Rule 66. This control approach was used in the State Air Implementation Plan, and has been tentatively accepted by EPA. As a result of this approach, some hydrocarbons considered to be reactive by EPA, are not considered in this control strategy.

The high yearly ambient oxidant reading is considered to be directly proportional to the amount of high reactive hydrocarbon emissions for that year. In other words, straight line proportional roll back of high reactive hydrocarbon emissions is used to predict the emissions reduction needed to meet the oxidant standard.

The base year of 1970 is used to make this prediction. On August 6, 1970, the yearly 1-hour high oxidant reading of .62 ppm was recorded at Riverside. The .67 ppm year high oxidant reading used by the California Air Resources Board (ARB) in the air implementation plan has since been rejected by the ARB. The State Plan showed a total of 195 tons/day of stationary source high reactive hydrocarbon emission, and 33 tons/day from aircraft in 1970. The 1970 emissions from other mobile sources (i.e., on-highway light and heavy duty gasoline vehicles and motorcycles) are calculated in Appendix A, and these emissions are 1023 tons/day. As indicated this number does not include the emissions from off-highway gasoline usage. However, this usage is considered negligible on the basis of data obtained from the ARB staff, which showed that current off-highway gasoline usage accounts for only slightly more than 2% of gasoline sales.

Based on the federal .08 ppm maximum 1-hour oxidant standard, the 1970 high 1-hour ambient oxidant reading of .62 ppm, and the 1970 emissions are determined as follows:

$$(195 + 33 + 1023) \frac{.08}{.62} = 161 \text{ tons/day}$$

II. Discussion of a Control Strategy Package to Meet the Federal .08 ppm 1-hour Oxidant Standard in July 1977

The strategies discussed in this package include those for which it was felt that sufficient information existed to claim or estimate emissions reductions. The exceptions to this are the VMT reduction strategies evaluated by TRW and De Leuw Cather. No VMT reductions are claimed in this report from these measures. Any VMT reduction that these strategies might produce, would lessen the amount of gas rationing that would be needed as a final last resort measure to meet the standard.

Aircraft emissions and their control are based on the State Plan emission inventory and an EPA estimate of 30% aircraft emissions-reductions determined as a result of conversations with EPA personnel. These emissions in 1977 are calculated to be

$$35 \times .7 = 24 \text{ tons/day}$$

The June 1977 emissions from light and heavy duty vehicles and motorcycles when taking into account only the emissions reduction that would result from present and proposed factory installed control devices, are determined in Appendix B. Using these emissions as a baseline in Appendix C, control strategies are applied to various segments of the light and heavy duty vehicle population and the resulting emissions reductions calculated. Gas rationing is the final strategy that is evaluated, and is used as a last resort to attain the standard. Gas rationing not only affects the emission from mobile sources, but also affects the emissions from gasoline marketing operations. This is discussed and reflected in the calculations of Appendices C and D. Appendix D contains the evaluation and discussion of stationary source control strategies.

A compilation of the strategies and their step-by-step reductions are shown in the following Table 1. The emissions reductions that are shown for each mobile control strategy b. thru g., are the reductions that can be expected by the addition of each strategy only after the strategies listed prior to it have been implemented. In other words, the emissions reductions are determined from an emissions base that has been altered by the strategies previously evaluated. As a result of this then, the reductions in ton/day of one strategy cannot be compared to the reductions obtained by another strategy because the emissions base is altered (i.e., lowered) after each strategy is applied.

Table 1 COMPILATION OF CONTROL STRATEGY AFFECTS ON JUNE 30, 1977

	Tons/Day
Allowable Emissions	+ 161
Stationary source emissions considering no additional controls since 1970 and considering 83% gas rationing	+ 153
Stationary Control Strategy Reductions	
a. Gasoline marketing control (considering 83% gas rationing)	- 11
b. Dry cleaning vapor control	- 6
c. Degreaser substitution	- 25
d. Rule 66 strengthening (50%)	- 45
Stationary Emissions Remaining	+ 66
Mobile source emissions from aircraft, on-highway light and heavy duty vehicles, and motorcycles	+ 477
Mobile Control Strategy Reductions	
a. Aircraft emission reductions	- 11
b. VSAD and PCV State retrofit	- 19
c. Inspection and maintenance	- 39
d. Vehicle evaporative control retrofit	- 26
e. Gaseous fuel conversion	- 12
f. Oxidizing catalyst retrofit	- 84
g. VMT reduction by gasoline rationing	- 191
Mobile Emissions Remaining	+ 95
Total Mobile and Stationary Emissions Remaining	+ 161

"EPA-APPENDIX A"

1970 SOUTH COAST AIR BASIN ON-HIGHWAY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EMISSION INVENTORY

This appendix details the information and calculations involved in determining the above mentioned inventory for light and heavy duty gasoline powered motor vehicles and 2 and 4 stroke motorcycles.

The following data were obtained from the California Department of Motor Vehicles (DMV), the California Highway Patrol, and the California Air Resources Board (ARB), and were supplied to EPA by the ARB:

Average vehicle age
Age distribution
Vehicle population
Miles driven per vehicle year

The emission factors and deterioration factors are from the EPA draft report "Interim Report on Motor Vehicle Emission Estimation." (1) The reactivity factors (i.e., fraction of hydrocarbon vapor that is highly reactive per LAAPCD Rule 66) for gasoline exhaust and gasoline evaporative and crankcase emission are obtained from the California Institute of Technology - Environmental Quality Laboratory Report "SMOG a Report to the People." (2) The miles traveled per vehicle years are obtained from the publication "1971 Motor Trunk Facts." (3) The motorcycle emission factors were obtained verbally from EPA sources Armstrong and Kircher.

The age distribution for heavy duty vehicles is assumed to be the same as that for light duty vehicles.

TABLE A-1

December 31, 1970

LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSION INVENTORY

Model Year	Average Age(yr.)	Vehicle Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm./mi)	Deterior-ation Factor	Conversion Factor $\frac{\text{(ton-yr.)}}{\text{(gm.-day)}}$	Reactivity Factor	Emissions $\frac{\text{(ton)}}{\text{(day)}}$
1971	1/8	.023	5.6×10^6	2,000	2.9	1.01	3.02×10^{-9}	.8	1.8
1970	3/4	.090	5.6×10^6	11,600	3.6	1.04	3.02×10^{-9}	.8	52.9
1969	1 3/4	.106	5.6×10^6	11,500	4.4	1.15	3.02×10^{-9}	.8	83.5
1968	2 3/4	.0971	5.6×10^6	10,200	4.5	1.21	3.02×10^{-9}	.8	73.0
1967	3 3/4	.0847	5.6×10^6	9,000	4.6	1.14	3.02×10^{-9}	.8	54.1
1966	4 3/4	.0898	5.6×10^6	7,700	6.0	1.29	3.02×10^{-9}	.8	72.4
1965	5 3/4	.0948	5.6×10^6	7,000	8.8	1.00	3.02×10^{-9}	.8	79.0
1964	6 3/4	.0838	5.6×10^6	6,000	8.8	1.00	3.02×10^{-9}	.8	59.9
1963	7 3/4	.0723	5.6×10^6	5,000	8.8	1.00	3.02×10^{-9}	.8	31.3
1962	8 3/4	.0597	5.6×10^6	4,400	8.8	1.00	3.02×10^{-9}	.8	31.3
1961	9 3/4	.0409	5.6×10^6	3,900	8.8	1.00	3.02×10^{-9}	.8	19.0
1960	10 3/4	.0367	5.6×10^6	3,800	8.8	1.00	3.02×10^{-9}	.8	16.6
1959 & earlier	11 3/4+	.1212	5.6×10^6	3,300	8.8	1.00	3.02×10^{-9}	.8	47.6
								Total	634.1

TABLE A-2

December 31, 1970

LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON CRANKCASE AND EVAPORATIVE EMISSION INVENTORY

Model Yr.	Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Yr.	Emission Factor (gm/mi)	Conversion Factor $\frac{(Ton/yr.)}{(gm/day)}$	Reactivity Factor	Emissions (Tons/Day
1971	.023	5.6×10^6	2,000	.5	3.02×10^{-9}	.67	.3
1970	.090	5.6×10^6	11,600	.5	3.02×10^{-9}	.67	5.9
1969	.106	5.6×10^6	11,500	3.0	3.02×10^{-9}	.67	41.4
1968	.0971	5.6×10^6	10,200	3.0	3.02×10^{-9}	.67	33.7
1967	.0847	5.6×10^6	9,000	3.0	3.02×10^{-9}	.67	25.9
1966	.0898	5.6×10^6	7,700	3.0	3.02×10^{-9}	.67	23.5
1965	.0948	5.6×10^6	7,000	3.0	3.02×10^{-9}	.67	22.6
1964	.0838	5.6×10^6	6,000	3.0	3.02×10^{-9}	.67	17.1
1963	.0723	5.6×10^6	5,000	3.8	3.02×10^{-9}	.67	15.6
1962	.0597	5.6×10^6	4,400	3.8	3.02×10^{-9}	.67	11.3
1961	.0409	5.6×10^6	3,900	3.8	3.02×10^{-9}	.67	6.9
1960	.0367	5.6×10^6	3,800	7.1	3.02×10^{-9}	.67	11.2
1959 & earlier	.1212	5.6×10^6	3,300	7.1	3.02×10^{-9}	.67	32.2
						Total	247.6

TABLE A-3

December 31, 1970

HEAVY DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSION INVENTORY

Model Year	Average Age (yr.)	Vehicle Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm./mi)	Deterioration * Factor	Conversion Factor (ton-yr.) / (gm.-day)	Reactivity Factor	Emissions (ton) / (day)
1971	1/8	.023	2.32×10^5	1,300	15	1.02	3.02×10^{-9}	.8	.3
1970	3/4	.090	2.32×10^5	7,500	15	1.09	3.02×10^{-9}	.8	6.2
1969	1 3/4	.106	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	11.3
1968	2 3/4	.0971	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	10.3
1967	3 3/4	.0847	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	9.0
1966	4 3/4	.0898	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	9.6
1965	5 3/4	.0948	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	10.1
1964	6 3/4	.0838	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	8.9
1963	7 3/4	.0723	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	7.7
1962	8 3/4	.0597	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	6.4
1961	9 3/4	.0409	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	4.4
1960	10 3/4	.0367	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	3.9
1959 & earlier	11 3/4+	.1212	2.32×10^5	10,000	19	1.00	3.02×10^{-9}	.8	12.9
									101.0

* Based on recommendation of EPA interim emission factor report, Pg. 8 (1)

TABLE A-4

December 31, 1970

HEAVY DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON CRANKCASE AND EVAPORATIVE EMISSION INVENTORY

Model Yr.	Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Yr.	Emission Factor (gm/mi)	Conversion Factor $\frac{(\text{Ton/yr.})}{(\text{gm/day})}$	Reactivity Factor	Emission (Tons/Da
1971	.023	2.32×10^5	1,300	3.0	3.02×10^{-9}	.67	.04
1970	.090	2.32×10^5	7,500	3.0	3.02×10^{-9}	.67	.95
1969	.106	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.49
1968	.0971	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.37
1967	.0847	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.19
1966	.0898	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.26
1965	.0948	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.34
1964	.0838	2.32×10^5	10,000	3.0	3.02×10^{-9}	.67	1.18
1963	.0723	2.32×10^5	10,000	3.8	3.02×10^{-9}	.67	1.29
1962	.0597	2.32×10^5	10,000	3.8	3.02×10^{-9}	.67	1.06
1961	.0409	2.32×10^5	10,000	3.8	3.02×10^{-9}	.67	.73
1960	.0367	2.32×10^5	10,000	8.2	3.02×10^{-9}	.67	1.41
1959 & earlier	.1212	2.32×10^5	10,000	8.2	3.02×10^{-9}	.67	4.67
						Total	17.98

TABLE A-5

December 31, 1970

2 Stroke Motorcycle Reactive Hydrocarbon Exhaust Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Ton Day
107,500	3,900	15	3.02×10^{-9}	.8	15.2

TABLE A-6

December 31, 1970

4 Stroke Motorcycle Reactive Hydrocarbon Exhaust Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Ton Day
175,500	3,900	3.3	3.02×10^{-9}	.8	5.5

TABLE A-7

December 31, 1970

4 Stroke Motorcycle Reactive Hydrocarbon
Crankcase Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Ton Day
175,500	3,900	.7	3.02×10^{-9}	.67	1.0

TABLE A-8

December 31, 1970

2 Stroke Motorcycle Reactive Hydrocarbon
Evaporative Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Ton Day
107,500	3,900	.32	3.02×10^{-9}	.67	.3

TABLE A-9

December 31, 1970

4 Stroke Motorcycle Reactive Hydrocarbons
Evaporative Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Ton Day
175,500	3,900	.35	3.02×10^{-9}	.67	.5

"EPA-APPENDIX B"

JUNE 30, 1977 SOUTH COAST AIR BASIN ON-HIGHWAY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EMISSION INVENTORY

(Based on the emissions control produced by new car
(i.e., factory installed) emission control devices)

This appendix details the information and calculations involved in determining the above mentioned inventory for light and heavy duty gasoline powered motor vehicles and two and four stroke motorcycles.

The following data were obtained from the California Department of Motor Vehicles (DMV), the California Highway Patrol, and the California Air Resources Board (ARB), and were supplied to EPA by the ARB:

Average vehicle age
Age distribution
Vehicle population
Miles driven per vehicle year

The emission factors and deterioration factors are from the EPA draft report "Interim Report on Motor Vehicle Emission Estimation." (1) The reactivity factors (i.e., fraction of hydrocarbon vapor that is highly reactive per LAAPCD Rule 66) for gasoline exhaust and gasoline evaporative and crankcase emission are obtained from the California Institute of Technology - Environmental Quality Laboratory Report "MSOG A Report to the People." (2) The miles traveled per vehicle year are obtained from the publication "1971 Motor Truck Facts." (3) The motorcycle emission factors were obtained verbally from EPA sources Armstrong and Kircher.

The age distribution for heavy duty vehicles is assumed to be the same as that for light duty vehicles.

The vehicle population in the South Coast Air Basin on June 30, 1977 is estimated by multiplying the statewide vehicle population in 1970 by a population growth factor that is adjusted to reflect the June 30 inventory date. This product is then multiplied by the adjusted 1977 South Coast Air Basin fraction of statewide vehicle population in the Basin on June 30, 1977 is shown below.

1970 Statewide Vehicle Population x (1 + 1970 to 77 Growth Factor x (June 77/Dec. 77) adjustment) x South Coast Basin Vehicle Population Factor = Basin Vehicle Population

$$11{,}250{,}000\ (1+.104 \times \frac{6.5}{7})\ .4918 = 6{,}070{,}000$$

The vehicle age distribution was adjusted to reflect the June 30 inventory by eliminating the .023 fraction of "next year" model vehicles, and also eliminating an estimated .017 fraction of present year model vehicles. The age distributions for the remaining years were then adjusted (i.e., increased) to reflect this change.

The calculation for determining the heavy duty vehicle population in the Basin in July 1, 1977 is shown below.

$$466{,}300\ (1+.104 \times \frac{6.5}{7})\ .4918 = 252{,}000$$

The calculation for determining the motorcycle population in the Basin in 1977 is shown below, using a DMV prediction for statewide motorcycle population and the same vehicle population fraction used in the previous two calculations.

$$771{,}800 \times .4918 = 330{,}000$$

TABLE B-1

June 30, 1977

LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSION INVENTORY

Model Year	Average Age (yr.)	Vehicle Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm./mi)	Deterioration Factor	Conversion Factor (ton-yr.) / (gm.-day)	Reactivity Factor	Emissions (ton) / (day)
1977	1/2*	.076*	6.07×10^6	5,800	.23	1.23	3.02×10^{-9}	8	1.8
1976	1 1/2	.110	"	11,500	.23	1.7	"	"	7.3
1975	2 1/2	.101	"	10,200	.23	1.23***	"	"	4.3
1974	3 1/2	.0883	"	9,000	2.7	1.14	"	"	39.5
1973	4 1/2	.0936	"	7,700	2.7	1.16	"	"	33.5
1972	5 1/2	.0988	"	7,000	2.7	1.18	"	"	32.3
1971	6 1/2	.0873	"	6,000	2.9	1.21	"	"	26.9
1970	7 1/2	.0753	"	5,000	3.6	1.28	"	"	24.5
1969	8 1/2	.0622	"	4,400	4.4	1.30	"	"	22.9
1968	9 1/2	.0426	"	3,900	4.5	1.35	"	"	14.7
1967	10 1/2	.0382	"	3,800	4.6	1.21	"	"	11.8
1966	11 1/2	.0312**	"	3,300	6.0	1.35	"	"	12.2
1965 and earlier	12 1/2	.095	"	3,300	8.8	1.0	"	"	40.5
								Total	272.2

*These data were changed and adjusted to reflect the fact that the inventory is for June 30, and not Dec. 31.

**An estimation made to allow for the application of a 1966 emission factor.

***This deterioration factor was changed (i.e., lowered) to reflect the fact that catalysts in 1975 can be changed after 25,000 miles, or approximately 2 years service.

TABLE B-2

June 30, 1977

LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON CRANKCASE AND EVAPORATIVE EMISSION INVENTORY

Model Yr.	Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Yr.	Emission Factor (gm/mi)	Conversion Factor (Ton/yr.)/(gm/day)	Reactivity Factor	Emissions (Tons/Day)
1977	.076	6.07×10^6	5,800	.2	3.02×10^{-9}	.67	1.08
1976	.110	"	11,500	.2	"	"	3.39
1975	.101	"	10,200	.2	"	"	2.52
1974	.0883	"	9,000	.2	"	"	2.15
1973	.0936	"	7,700	.2	"	"	1.77
1972	.0988	"	7,000	.2	"	"	1.70
1971	.0873	"	6,000	.5	"	"	3.21
1970	.0753	"	5,000	.5	"	"	2.31
1969	.0622	"	4,400	3.0	"	"	10.10
1968	.0426	"	3,900	3.0	"	"	6.12
1967	.0382	"	3,800	3.0	"	"	5.35
1966	.0312	"	3,300	3.0	"	"	3.79
1965 and earlier	.095	"	3,300	3.4*	"	"	13.10
						Total	56.59

*An estimate to reflect the 1965 and earlier average emission factor.

TABLE B-3

June 30, 1977

HEAVY DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSION INVENTORY

Model Year	Average Age (yr.)	Vehicle Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm./mi)	Deterioration Factor	Conversion Factor (ton-yr.)/(gm.-day)	Reactivity Factor	Emissions (ton)/(day)
1977	1/2	.76	2.52×10^5	5,000	2.4	1.06	3.02×10^{-9}	.8	.59
1976	1-1/2	.110	"	10,000	2.4	1.15	"	"	1.60
1975	2-1/2	.101	"	"	"	1.20	"	"	1.77
1974	3-1/2	.0883	"	"	7.8	1.32	"	"	5.55
1973	4-1/2	.0936	"	"	"	1.25	"	"	5.56
1972	5-1/2	.0988	"	"	9.9	1.27	"	"	7.55
1971	6-1/2	.0873	"	"	15.0	1.29	"	"	10.30
1970	7-1/2	.0753	"	"	15.0	1.31	"	"	9.05
1969	8-1/2	.0622	"	"	19.0	1.0	"	"	7.22
1968 & Earlier	9-1/2+	.2070	"	"	19.0	1.0	"	"	24.00
									73.2

TABLE B-4

June 30, 1977

HEAVY DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON CRANKCASE AND EVAPORATIVE EMISSION INVENTORY

Model Yr.	Age Distribution	Total Basin Vehicle Population	Miles Driven Per Vehicle Yr.	Emission Factor (gm/mi)	Conversion Factor $\frac{(Ton/yr.)}{(gm/day)}$	Reactivity Factor	Emissions (Tons/Day)
1977	.76	2.52×10^5	5,000	.8	3.02×10^{-9}	.67	.16
1976	.110	"	10,000	.8	"	"	.45
1975	.101	"	"	.8	"	"	.41
1974	.0883	"	"	.8	"	"	.36
1973	.936	"	"	.8	"	"	.38
1972	.988	"	"	3.0	"	"	1.52
1971	.0873	"	"	3.0	"	"	1.34
1970	.0753	"	"	3.0	"	"	1.16
1969	.0622	"	"	3.0	"	"	.96
1968	.0426	"	"	3.0	"	"	.66
1967	.0382	"	"	3.0*	"	"	.58
1966	.0312	"	"	3.0*	"	"	.48
1965 +	.095	"	"	3.4*	"	"	1.66
						Total	10.10

*These heavy duty vehicle hydrocarbon emission factors of Ref. (1), Table 16, were changed in order to reflect the fact that PCV devices were installed on heavy duty gasoline vehicles on the same schedule as the light duty vehicles.

TABLE B-5

June 30, 1977

2 Stroke Motorcycle High Reactive Hydrocarbon Exhaust Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Emissions Ton Day
144,000	3,900	15.0	3.02×10^{-9}	.8	20.4

TABLE B-6

June 30, 1977

4 Stroke Motorcycle High Reactive Hydrocarbon Exhaust Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Emissions Ton Day
236,000	3,900	3.3	3.02×10^{-9}	.8	7.36

TABLE B-7

June 30, 1977

4 Stroke Motorcycle High Reactive Hydrocarbon Crankcase Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Emissions Ton Day
236,000	3,900	.7	3.02×10^{-9}	.67	1.3

TABLE B-8

June 30, 1977

2 Stroke Motorcycle Reactive Hydrocarbon
Evaporative Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Emissions Ton Day
144,000	3,900	.32	3.02×10^{-9}	.67	.36

TABLE B-9

June 30, 1977

4 Stroke Motorcycle Reactive Hydrocarbon
Evaporative Emission Inventory

Vehicle Population	Miles Driven Per Vehicle Year	Emission Factor (gm/mi)	Conversion Factor (ton-yr) (gm-day)	Reactivity Factor	Emissions Ton Day
236,000	3,900	.35	3.02×10^{-9}	.67	.65

EPA-APPENDIX C

June 30, 1977 EMISSION REDUCTIONS FROM VARIOUS CONTROL STRATEGIES IN THE SOUTH COAST AIR BASIN FOR ON-HIGHWAY GASOLINE VEHICLES - HIGH REACTIVITY HYDROCARBONS

I. Strategy Basis and Background

The 1970 and 1977 high reactive hydrocarbon emissions from light and heavy duty vehicles and from 2 and 4 stroke motorcycles when considering emissions control based only on control devices installed on new vehicles, are shown in Table C-1. This table is a compilation of Appendix A and B calculation results.

Using the emissions shown in the 1977 column as a base, various control strategies are applied, and the emissions reductions obtained by these control strategies are shown in the various subsections of Section II. It should again be pointed out and emphasized that the emission reductions in Tons/Day that are calculated for each strategy. are the reductions that can be expected by the addition of a particular strategy only after the strategy or strategies previously evaluated have been implemented. In other words, the emission reductions are determined from an emission base that has been reduced by the strategies previously evaluated. As a result of this then, the reduction in Ton/Day of one strategy cannot be compared to the reduction obtained by another strategy because the emission base is altered (i.e., lowered) after each strategy is applied.

The total emissions remaining and the emissions remaining for each model year after implementing each strategy on the two types of vehicles (light and heavy duty) and on the two sources of emission from these vehicles (exhaust and crankcase and evaporative emissions), are shown in Tables C-2, C-3, C-4 and C-5 in the following section.

TABLE C-1

HIGH REACTIVE HYDROCARBON EMISSIONS FROM LIGHT AND HEAVY DUTY VEHICLES AND MOTORCYCLES

(A Compilation of Appendix A and B Results)

	Tons/Day	
	1970	1977
Reactive Hydrocarbon Exhause Emissions		
a. Light duty vehicles (considering only factory installed control devices)	634.1	272.0
b. Heavy duty vehicle (considering only factory installed control devices)	101.0	73.2
c. 2-Stroke Motorcycle (no controls)	15.2	20.4
d. 4-Stroke Motorcycle (no controls)	5.5	7.4
Reactive Hydrocarbon Crankcase and Evaporative Emissions		
a. Light duty vehicle (considering only factory installed control devices)	247.6	56.6
b. Heavy duty vehicle (considering only factory installed control devices)	18.0	10.1
c. 2 and 4 Stroke Motorcycle (no controls)	1.8	2.3
Total	1023.2	442.0

TABLE C-2
June 30, 1977

STRATEGY RUNNING INVENTORY LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSIONS

Emissions ($\frac{\text{Tons}}{\text{Day}}$)

Model Year	Appendix B Emissions with New Car Controls Only	VSAD & PCV Retrofit	Inspection & Maintenance	Evaporative Control Retrofit	Gaseous Fuel Conversion Retrofit	Oxidizing Catalyst Retrofit	82.4% Gas Rationing
1977	1.8	1.8	1.6	1.6	1.6	1.60	.28
1976	7.3	7.3	6.4	6.4	6.4	6.40	1.13
1975	4.3	4.3	3.8	3.8	3.8	3.80	.67
1974	39.5	39.5	34.8	34.8	30.2	18.90	3.30
1973	33.5	33.5	29.5	29.5	27.0	16.90	3.00
1972	32.3	32.3	28.4	28.4	26.6	16.60	2.92
1971	26.9	26.9	23.7	23.7	22.1	13.70	2.41
1970	24.5	22.0	19.4	19.4	19.4	12.10	2.13
1969	22.9	20.6	18.1	18.1	18.1	11.30	1.97
1968	14.7	13.2	11.6	11.6	11.6	7.25	1.28
1967	11.8	10.6	9.3	9.3	9.3	5.81	1.02
1966	12.2	11.0	9.7	9.7	9.7	6.06	1.07
1965 & Earlier	40.5	33.7	29.7	29.7	29.7	29.70	5.13
TOTAL	272.2	256.7	226.0	226.0	215.5	150.12	26.31

TABLE C-3
June 30, 1977

STRATEGY RUNNING INVENTORY
HEAVY DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON EXHAUST EMISSIONS

Emissions ($\frac{\text{Tons}}{\text{Day}}$)

Model Year	Appendix B Emissions With New Car Controls Only	VSAD & PCV Retrofit	Inspection & Maintenance	Evaporative Control Retrofit	Gaseous Fuel Conversion Retrofit	Oxidizing Catalyst Retrofit	82.4% Gas Rationing
1977	.59	.59	.52	.52	.52	.52	.09
1976	1.60	1.60	1.41	1.41	1.41	1.41	.25
1975	1.77	1.77	1.56	1.56	1.56	1.56	.27
1974	5.55	5.55	4.88	4.88	4.88	3.05	.54
1973	5.56	5.56	4.89	4.89	4.89	3.06	.54
1972	7.55	7.55	6.64	6.64	6.64	4.15	.73
1971	10.39	10.30	9.06	9.06	9.06	5.66	1.00
1970	9.05	9.05	7.96	7.96	7.96	4.98	.88
1969	7.22	7.22	6.35	6.35	6.35	3.97	.70
1968 & Earlier	24.00	22.10	19.40	19.40	19.40	15.50	2.73
TOTAL	73.19	71.29	62.67	62.67	62.67	43.86	7.73

TABLE C-4
June 30, 1977

STRATEGY RUNNING INVENTORY
LIGHT DUTY GASOLINE VEHICLE HIGH REACTIVE HYDROCARBON CRANKCASE AND EVAPORATIVE EMISSIONS

Emissions $(\frac{\text{Tons}}{\text{Day}})$

Model Year	Appendix B Emissions with New Car Controls Only	VSAD & PCV Retrofit	Inspection & Maintenance	Evaporative Control Retrofit	Gaseous Fuel Conversion Retrofit	Oxidizing Catalyst Retrofit	82.4% Gas Rationing
1977	1.08	1.08	1.08	1.08	1.08	1.08	.19
1976	3.39	3.39	3.39	3.39	3.39	3.39	.60
1975	2.52	2.52	2.52	2.52	2.52	2.52	.44
1974	2.15	2.15	2.15	2.15	1.78	1.78	.31
1973	1.77	1.77	1.77	1.77	1.56	1.56	.27
1972	1.70	1.70	1.70	1.70	1.50	1.50	.26
1971	3.21	3.12	3.12	3.21	2.87	2.87	.51
1970	2.31	2.31	2.31	2.31	2.31	2.31	.41
1969	10.10	10.10	10.10	1.70	1.70	1.70	.30
1968	6.12	6.12	6.12	1.04	1.04	1.04	.18
1967	5.35	5.35	5.35	.91	.91	.91	.16
1966	3.78	3.78	3.79	.64	.64	.64	.11
1965 & Earlier	13.10	11.90	11.90	11.90	11.90	11.90	2.10
TOTAL	56.59	55.39	55.39	34.32	33.20	33.20	5.84

TABLE C-5

June 30, 1977

Strategy Running Inventory

Heavy Duty Gasoline Vehicle High Reactive Hydrocarbon Crankcase and Evaporative Emissions

Emissions ($\frac{\text{Tons}}{\text{Day}}$)

Model Year	Appendix B Emissions With New Car Controls Only	VSAD & PCV Retrofit	Inspection & Maintenance	Evaporative Control Retrofit	Gaseous Fuel Conversion Retrofit	Oxidizing Catalyst Retrofit	82.4% Gas Rationing
1977	.16	.16	16	.16	.16	.16 →	.03
1976	.45	.45	.45	.45	.45	.45 →	.08
1975	.41	.41	.41	.41	.41	.41 →	.07
1974	.36	.36	.36	.36	.36	.36 →	.06
1973	.38	.38	.38	.38	.38	.38 →	.07
1972	1.52	1.52	1.52 →	.41	.41	.41 →	.07
1971	1.34	1.34	1.34 →	.36	.36	.36 →	.06
1970	1.16	1.16	1.16 →	.31	.31	.31 →	.05
1969	.96	.96	.96 →	.26	.26	.26 →	.05
1968	.66	.66	.66 →	.18	.18	.18 →	.03
1967	.58	.58	.58 →	.16	.16	.16 →	.03
1966	.48	.48	.48 →	.13	.13	.13 →	.02
1965 & EARLIER	1.66 →	1.46	1.46	1.46	1.46	1.46 →	.26
TOTAL	10.11	9.92	9.92	5.03	5.03	5.03	.88